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# MOTION PICTURE ENGINEERS

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# The Society of Motion Picture Engineers

## Its Aims and Accomplishments

The Society was founded in 1916, its purpose as expressed in its constitution being "advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein, and the maintenance of a high professional standing among its members."

The Society is composed of the best technical experts in the various research laboratories and other engineering branches of the industry in the country, as well as executives in the manufacturing and producing ends of the business. The commercial interests also are represented by associate membership in the Society.

The Society holds two conventions a year, one in the spring and one in the fall. The meetings are generally of four days' duration each, and are held at various places. At these meetings papers are presented and discussed on all phases of the industry, theoretical, technical, and practical. Demonstrations of new equipment and methods are often given. A wide range of subjects is covered, and many of the authors are the highest authorities in their distinctive lines.

Papers presented at conventions, together with contributed articles, translations and reprints, abstracts and abridgments, and other material of interest to the motion picture engineer are published in the JOURNAL of the Society.

The publications of the Society constitute the most complete existing technical library for the motion picture industry.

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OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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# THE PROBLEM OF MOTION PICTURE PROJECTION FROM CONTINUOUSLY MOVING FILM*

FORDYCE TUTTLE AND CHAS. D. REID**

***Summary.***—*The advantages claimed for non-intermittent projectors are presented, followed by a list of questions that the writers think should be answered with regard to any projector of this type. The various projector types are then classified according to the optical means used to form a fixed image. Two types of error are noted and each type of projector listed is discussed, keeping these in mind. A reference table is appended to serve as a rapid review.*

It has been the privilege of the authors to review the several hundred patents which have been granted on non-intermittent motion picture projectors. We have found that the problem of producing a satisfactory screen image from moving film by means of moving optical parts is not a simple one, and it seems desirable to discuss the difficulties encountered in the design of the several types of such projectors.

Since any non-intermittent projector would have to compete with the intermittent machine, and since the optics of the former admittedly will have to be more complicated, we must consider what offsetting advantages may be possessed by the non-intermittent projector.

A summary of the advantages claimed follows:

(1). There might be less wear and tear on film which is pulled at a constant linear velocity through a machine than on film which is intermittently accelerated by a machine.

(2). There would probably be less difficulty in running film already damaged through a non-intermittent machine. With the intermittent projector, a few successive damaged perforations cause the loss of the loop, and further damage to the perforations until the loop is restored. The non-intermittent machine will usually restore itself to a running condition even though the film be damaged over a considerable length.

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* Reprinted from *J. Opt. Soc. of America*, **22** (Feb., 1932), No. 2, p. 39.

** Eastman Kodak Co., Rochester, N. Y.

(3). There is a possibility that there might be more total light to the screen, since no shutter is needed to cover up the movement of the film.

(4). There might be a better portrayal of action if each picture is allowed to blend into the successive picture.

(5). If the light to the screen can be kept constant at all times during the projection cycle, it may be possible to eliminate flicker entirely. Some inventors have argued that the interruptions of the light, even though of frequencies high enough to eliminate visible flicker, cause some eye-strain.

(6). The ideal non-intermittent machine might be much less noisy. In the present intermittent machine, certainly a large part of the noise comes from the intermittent pull-down and from the film moving intermittently in the loops and through the gate.

(7). There might be less trouble with wear in the non-intermittent machine. In the intermittent machine, wear in the pull-down parts causes unsteadiness.

(8). In a portable sound-on-film projector, there might be a number of mechanical advantages in not having to have the film moving intermittently at the picture aperture and continuously at the sound gate.

None of these possible advantages is great enough to offset any serious imperfections in the projected picture, such as unsteadiness, distortion, and poor definition. This does not mean that we would be right in insisting on theoretical perfection in the projected picture. Practically every non-intermittent machine involves approximations, and in studying these machines we have found it desirable to set up more or less arbitrary standards for theoretical steadiness, distortion, and definition. If we make these standards about equivalent to the practical standards of the intermittent machine, we could allow about the following approximations:

(1). Steadiness of the center part of the picture plus or minus 0.0005 inch (referred to the film frame).

(2). Distortion movement in the corners of the frame plus or minus 0.001 inch.

(3). Definition.

(*a*). In the center of the frame 0.001 inch (circle of confusion).

(*b*). In the corners 0.002 inch.

With intermittent equipment, considering the errors in the camera,

the printer, and the projector, we are fortunate if successive frames are registered in the projector gate closer than plus or minus 0.0005 inch, which makes our steadiness tolerance seem reasonable. Twice the movement has been allowed in the corners of the frame that was thought permissible for the center of the frame, because of the belief that the eye is not particularly concerned with movement away from the center of interest. The definition tolerances used here are equivalent to those usually found in practice in motion picture work. With regard to definition, it has been observed that if the definition is poor during some parts of the projection period, but good during other parts of the projection period, the eye sees definition that is somewhat better than the arithmetical time average of the definition.

Before listing the different classes of non-intermittent projectors and outlining the difficulties encountered in their design, the following questions are presented as those which we think should be answered with regard to any of these projectors.

### QUALITY OF PROJECTED PICTURE

(1). Is the center point of the picture stationary within sensible limits?

(2). Does distortion give a "rubbery" effect in the picture, or does it make corner definition too poor to be acceptable?

(3). Is the definition in the picture comparable with intermittent projection?

(4). Is the picture made flat by flare from many free glass-air surfaces?

(5). Does the system permit of fading out of one picture into the next?

### AMOUNT OF LIGHT FOR PROJECTION

(6). Does the system impose limitations on the $f$ aperture of the projection lenses?

(7). Is the light lost by passing through many surfaces or from reflections serious?

(8). Is the light to the screen during the change-over period equal to the light when projecting wholly from a single frame, or is it necessary to introduce diaphragms or shutters which cut down on the light?

(9). Does the system require a special moving condenser system?

#### PRECISION REQUIREMENTS

(10). If cams are used, what is the precision required in cutting the cam? Are the surfaces such that they can be cut with precision from point to point?

(11). What precision is required in the gear trains connecting film drive with optical displacement means?

(12). What precision is required in the sprocket exactly fitting the film? Is a jump back as one tooth leaves a perforation and the next tooth starts to drive serious?

(13). What precision is required in initial adjustment?

(14). What precision is required in the making or matching of optical parts?

#### SPECIAL LIMITATIONS

(15). Does the system impose impractical limitations on the equivalent focus or the back focus of lenses?

(16). Does the system demand ridiculous physical dimensions in the projector?

(17). Does the system necessitate a fixed screen distance or a fixed magnification?

(18). Is the system capable of projecting lenticulated color film? (Kodacolor.)

(19). Is a special arrangement of pictures on the film or a special type of film assumed?

(20). What type of framing device is required?

#### NOISE

(21). Are all moving parts moving with constant angular velocity and can all of them be counterbalanced?

(22). How does the mass and moment of inertia of reciprocating parts compare with the mass and moment of inertia of the intermittent projector parts?

#### OPTICAL REQUIREMENTS DIFFICULT TO FULFILL

(23). Is it necessary to use simple lenses of large *f* apertures covering large fields?

(24). Is it assumed that a single image-forming reflector working with a large aperture will cover a considerable field?

(25). Is it necessary to assume that a warped reflecting or refracting optical part can be made with great precision?

(26). Does the system demand the use of large aperture crossed cylindrical lenses to work as a well corrected spherical lens?

It is conceivable that any device for refracting or reflecting light might be used to give an optical displacement to an image which would compensate for the movement of the film. The following list indicates the elements which have been used, with a very short description of how they were moved.

*Moving Lenses*
- Reciprocating lens
- Linear motion of lenses in restricted path
- Circular motion (optical axes describing cylinder)
- Circular motion (optical axes radial)
- Circular motion of cylindrical lenses

*Plane Parallel Plates*
- Uniformly rotating cube or hexagonal prism
- Cam rotated plate
- Uniformly rotating plate with normal to the plate describing a cone

*Refracting Prisms*
- Cam actuated variable angle liquid prism
- Uniformly rotating warped refracting elements
- Equal prisms, cam rotated equally and oppositely

*Reflecting Plane Mirrors*
- Cam reciprocated mirror
- Cam actuated series of mirrors
- Uniform rotating drum of mirrors
- Helical reflecting surfaces
- Rotating rhombs
- Moving right angle reflectors

*Skewed Image Forming Elements*
- Concave spiraled mirror
- Spiraled lens

In the discussion of these displacement means, we would like to point out two types of errors that occur:

(1). Errors that are inherent in the displacement means employed.

(2). Errors that result from the method used in moving the displacement means.

### MOVING LENSES

Perfect lenses can be moved theoretically in such a manner that there is no inherent defect in the displaced image produced. In practice the means of moving the lenses and the use of simple lenses introduce difficulties.

If we move a lens, as in Fig. 1, in such a way that a straight line at all times passes through the center of the picture frame, the center of the lens and the center of the screen, we will have a stationary image

on the screen from film which is moving. We can design a cam which will reciprocate a single lens in this manner, but we must have a shutter which will cover up the return of the lens, and must introduce flicker blades which will give high-frequency interruptions. Further, the cam would have to be accurate to plus or minus 0.0005 inch. The mass we are accelerating in such a system is larger than in an

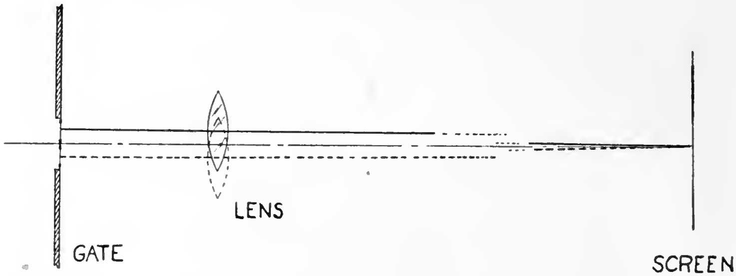


FIG. 1. Optical compensation for film motion by a single moving lens.

intermittent projector, and the same aperture lens can not give the same amount of light to the screen without a larger source or a moving condenser system.

Our first attempt at improvement on this system probably would be to try to have a series of lenses moving in a straight path in front of the film so spaced that when one lens is following one frame from

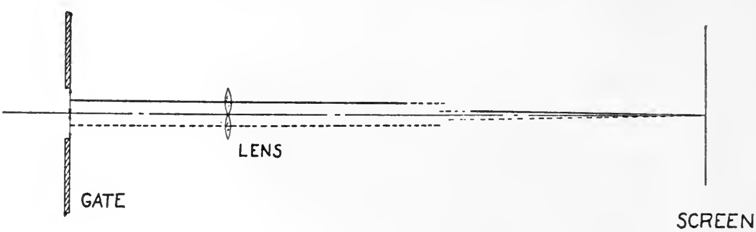


FIG. 2. Optical compensation for film motion by a plurality of moving lenses.

the top to the bottom of a two-frame aperture, the next lens is ready to follow the next frame. This system would allow us to do without the shutter for covering the return of the lens. It would be very difficult, however, to keep the light to the screen constant as we change from one frame to the next, and we would very likely end up with some type of shutter or diaphragm in the system which would reduce the light.

With two lenses in the position shown in Fig. 2, we can see that the physical diameter of the lenses is limited to a little less than the height of the frame. If the lens has a focal length long enough to cover the frame satisfactorily, we find that this limits the *f* aperture

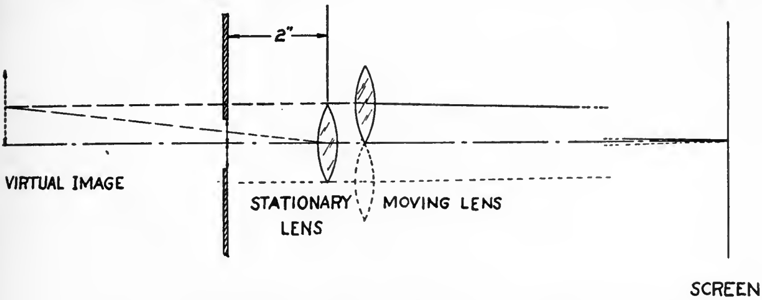


FIG. 3. Optical compensation for film motion by a plurality of moving lenses and a fixed lens forming a virtual image of moving film.

to a maximum of something like *f*/4, if we allow a minimum of lost space for the mount.

We can gain considerably in the aperture of the system if we use the arrangement shown in Fig. 3. A stationary lens subtending an

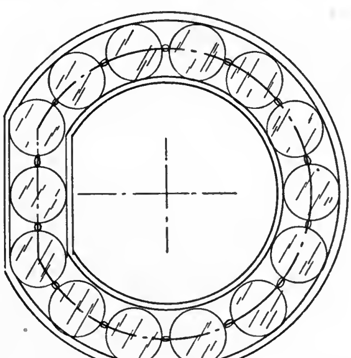

FIG. 4. One type of constricted path to give a linear motion to the moving lenses.

*f*/2 angle forms an enlarged virtual image of the film and the moving lenses move so that a straight line connects the center of the virtual image, the center of the moving lens, and the center of the screen. With 16-mm. film projected with the equivalent of a 2 inch lens, we

can have $f/2$ light to the screen at all times using moving lens elements which have apertures of only about $f/6$. With this system the ratio of the physical diameter of the moving element to the diameter of the stationary lens will determine the manner in which we may fade out

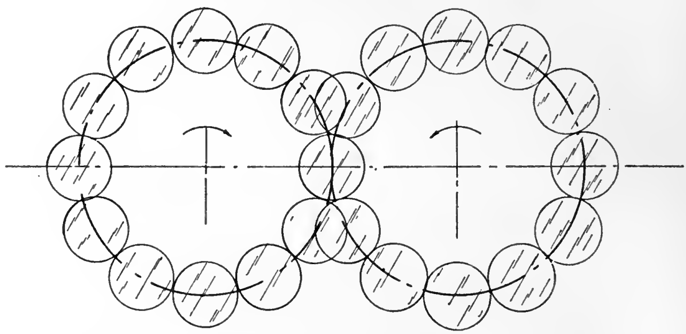

FIG. 5. Two wheels of lenses used to avoid the horizontal displacement produced by a single wheel.

of one picture into the next. If the diameter of the moving element is equal to the diameter of the stationary element, we will be constantly changing from one picture to the next. If the diameter of the moving element is much larger than the diameter of the stationary lens, we may divide the projection cycle so that during only half the time we are fading out from one picture to the next.

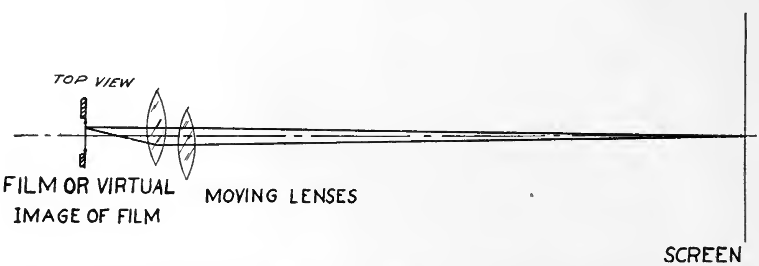


FIG. 6. Optical diagram showing the paths of rays through the double wheel of lenses.

With 35-mm. film projected with the equivalent of a 5-inch lens, we can get $f/2$ light again by using $f/6$ elements. With either film, if we can afford to increase the equivalent focus of the projection system, we can use moving elements which have smaller $f$ apertures

and have to cover smaller angular fields. Thus, we see that it may become possible for us to use comparatively simple moving lenses which is much better than having to use and to move a lot of well corrected lenses.

Other arrangements of a moving-lens optical system are possible. The moving lenses working on real or virtual objects can be used to form stationary real or virtual images. It is possible also to consider negative lenses in some cases for the moving lenses. Detailed discussion of all types is beyond the scope of this paper.

The problem of moving lenses in a straight path at a constant linear speed past the gate is not very easily solved mechanically. Several inventors have shown lenses in a belt which move in a restricted path as shown in Fig. 4, with the lenses either linked together or crowding each other along in a channel with a drive for the lenses supplied at some circular part of the path by some kind of rotating sprocket. Such a system, however, is usually noisy and inconvenient.

Fig. 5 shows the lenses arranged about a wheel. A single wheel would give the lenses an undesired horizontal displacement equal to the sagitta of the arc over which the lens is used. The optical effect of the horizontal displacement can be offset, however, if a similar wheel of lenses rotating about another axis is used as shown in Fig. 5. Fig. 6 is a top view of the lenses arranged in two wheels, showing how the horizontal displacements of the two lenses are opposite; they can be made to give zero optical displacement, if the focal length and the magnification for each lens are correct. The vertical component of the displacement varies as the sine of the angle through which the lens wheel is rotated. If we turn the wheels at a constant angular velocity, we will find it necessary then to have the film pass over a curved gate, if we insist that the image of the center point of the frame be made exactly stationary on the screen. The use of this curved gate, however, will introduce distortion in the picture. By making a compromise between distortion and steadiness, satisfactory projection can be obtained with the system described if the two wheels used each contain a sufficient number of lenses.

Fig. 7 shows another arrangement of lenses in a wheel. This arrangement of lenses, when used with a straight gate, will give undesirable keystoning of the image on the screen, since all parts of the film are not the same distance from the plane of the lens. Even a curved gate will not rid us of this defect for the image plane is not fixed. Fig. 8 shows the way the image surface shifts with respect

to the screen. However, if enough lenses are used in the wheel, satisfactory projection can be achieved.

The problem of moving cylindrical lenses in such a manner that the image will appear stationary is not as difficult as is the problem

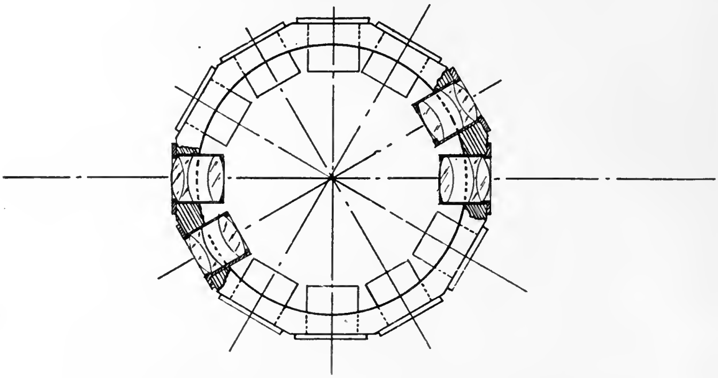

FIG. 7. A drum of lenses used for optical compensation.

of moving spherical lenses, since we do not have to worry about any horizontal displacement of the lens element in moving down across the gate. The difficulty of using cylindrical lenses is an optical one. It is necessary to assume that crossed cylindrical components, one

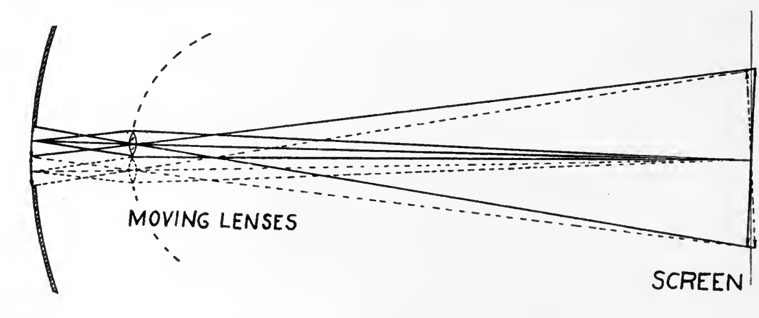


FIG. 8. The optical diagram for the system shown in Fig. 7.

moving, one stationary, can be designed to behave like a well corrected spherical lens.

REFRACTING PRISM

The refracting prism stationary in the beam produces defects in the image, giving errors of the first type. The problem of changing the

refracting angle of the prism in a satisfactory manner is difficult and in some cases produces errors of the second class.

If the prism is used in the beam on the long optical side, as shown in Fig. 9, or even in collimated light, we produce distortion in the image. If the motion picture frame to be projected is entirely above the

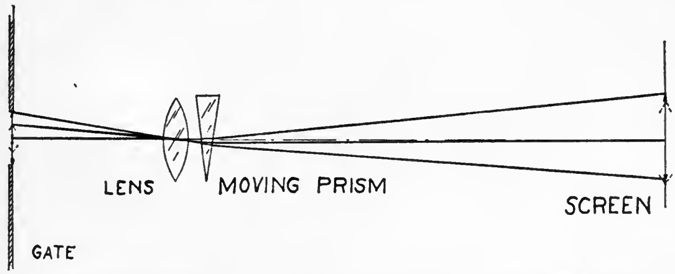


FIG. 9. The distortion produced by a prism on the long optical side of the projection lens.

optical axis of the lens and if we use a prism strong enough so that the light from the center point of the picture passing through at minimum deviation will be deviated so as to fall on the center of the screen, light from the top of the frame will pass through the prism at some angle differing from minimum deviation and will be bent more

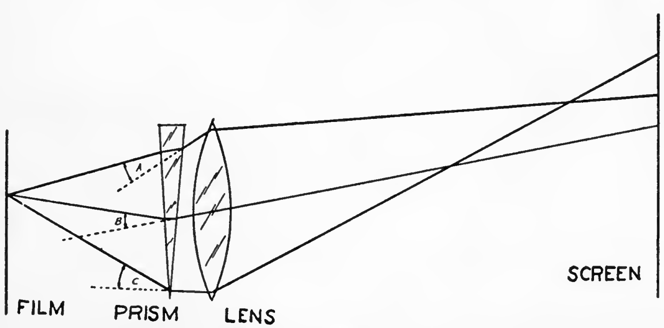


FIG. 10. The astigmatic effect caused by a prism on the short optical side of the projection lens.

than it should be. Light from the bottom of the frame will also be bent more than it should be. This will cause a lengthening of the top part of the image and a shortening of the bottom part of the image. If the prism is used on the short optical side of the lens, as shown in Fig. 10, light from a point on the film going to various parts

of the lens will be deviated varying amounts, and the point will be imaged on the screen as a line of considerable length.

Fig. 11 shows the departure in the angle of deviation from minimum deviation for rays passing through prisms at various incident angles. That these departures are serious is shown from a consideration of the fact that a departure of one minute in angle with a 2-inch lens would produce a displacement in the center part of the picture equivalent to 0.001 inch on the film frame, if the prism is assumed to be close to the

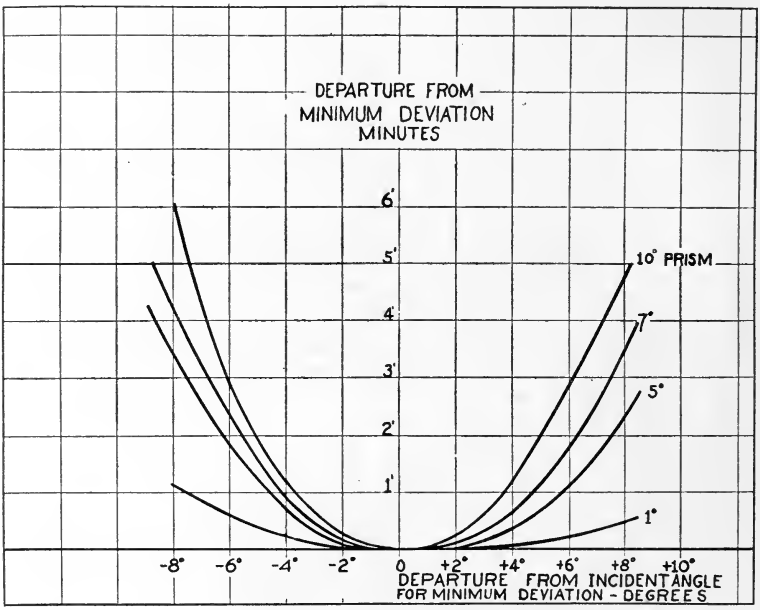


FIG. 11. The departure from minimum deviation produced by changing incident angle.

lens or on the long optical side. If the frame subtends an angle of 10 degrees at the lens, a 10-degree prism is necessary to shift the image one-half frame on the screen. If we consider the center part of the picture at all times passing through the prism at minimum deviation, rays from the top of the picture will be incident on the prism, at angles differing from the incident angle for minimum deviation by 5 degrees. This would be serious. However, it may be perfectly feasible to use a refracting prism on the long optical side

if the film frame subtends a small angle at the lens, or on the short optical side if the lens subtends a small angle at the film frame.

Fig. 12 shows a method by means of which we might partially correct for deviation troubles. By using two prisms so tilted with respect to each other that the ray which passes through the first

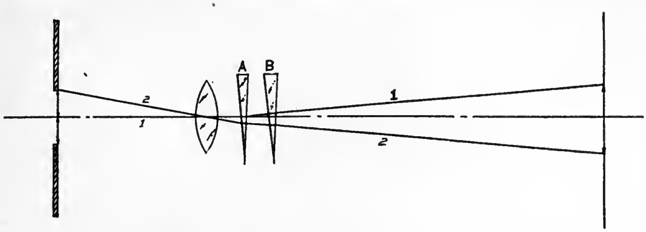


FIG. 12. A suggestion to eliminate the distortion caused by the variation of deviation of a prism with incident angle.

prism at an angle differing greatest from minimum deviation goes through the second prism at minimum deviation, and the ray passing through the first prism at minimum deviation passes through the second prism at an angle differing greatest from minimum deviation, the total deviation produced in the two rays considered will be practically equal.

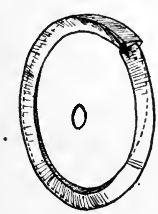


FIG. 13. A method of continuously changing the angle of deviation of a prism to produce optical compensation.

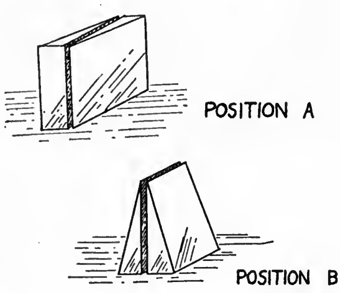


FIG. 14. A second method of continuously changing the angle of deviation of a (compound) prism.

As the film frame moves down over the gate, it is necessary to change the refracting angle of the prism to keep the center point of the image stationary. This changing of the angle of the prism is an awkward problem. Two methods are fairly feasible. The first is shown in Fig. 13 and consists of an annular disk which is ground so

that the refracting angle gradually changes from a prism with its thick side toward the center of the disk to a plane parallel plate and then to a prism with its thick side toward the circumference of the disk. The use of this warped refracting element in a projector introduces a skew distortion in the picture in addition to the distortions already discussed for the fixed prism. These new distortions become small if the prism disk is very large. The use of two warped refracting elements may allow cancellation of the skew distortion. Such an element is very difficult to make. Of course, it would be very difficult to achromatize it. It might be argued that it is not necessary to achromatize prismatic elements which appear in rapid succession first base side up and then base side down in the beam because persistence of vision would make superimposed complementary colored fringes appear nearly colorless. The trouble with this argument, however, is that the limit of definition of a horizontal line becomes the width of the spectral image of that line.

Another method of changing the refracting angle of prism elements is shown in Fig. 14. Two equal prisms placed with their emergent and entrance faces together may form a compound prism that will act as a plane parallel plate if the thick side of one is placed opposite the thin side of the other, as shown in position *A*. Now, if these prisms are each rotated through 90 degrees in opposite directions, we may arrive to the position *B*, which gives us a compound prism of twice the power of its component prisms. It will be noted that any horizontal displacement produced by one prism is offset by an equal but oppositely directed horizontal displacement produced by its companion prism. The vertical refracting angle, however, varies sinusoidally from zero to twice the refracting angle of the single prism. When prisms of this type are used in a non-intermittent projector, it is necessary to reciprocate them angularly with some cam motion and to have a shutter to cover the return.

## PLANE PARALLEL PLATE

The mere presence of a tilting plane parallel plate used in the beam of light produces defects in the image, while the method of tilting it also presents some difficulties.

The plane parallel plate used in a non-intermittent projector will have to be used on the short optical side of the projector system, or else be tremendously thick, since the displacement produced by the plate is a parallel one rather than an angular one. On the film side

of the lens a parallel displacement of a fraction of an inch will compensate for the full movement of the film and shift the screen image several feet.

Fig. 15 shows the displacement produced by a plane parallel plate, and Fig. 16 shows the variation of this displacement with the angle of tilt of the plate for a one-inch and a half-inch plate. It will be ob-

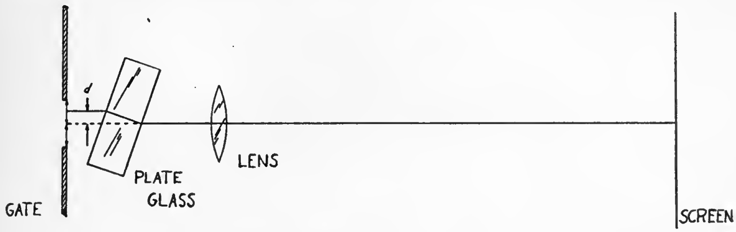


FIG. 15. The type of displacement produced by a plane parallel plate.

served that the relation is not a linear one, and hence the proper movement of the plates constitutes a problem unless the motion is to be controlled by a cam surface. The use of a plane parallel plate normal to the axis introduces spherical aberration and astigmatism. Fig. 17 shows how a point on the axis of the lens is imaged as a circle of considerable diameter on the screen. Fig. 18 shows the direction

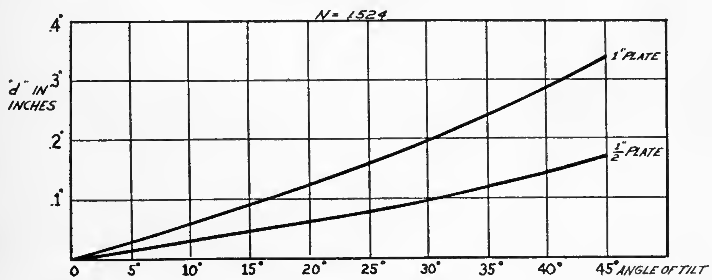


FIG. 16. The relation between the displacement produced by a plane parallel plate and the angle of tilt of the plate.

of rays from a point off the axis of the lens if the rays pass through a tilted plane parallel plate on the short optical side of the lens. The apparent definition on the film is affected, then, by the use of the plate and the position of the plate. If a 2-inch $f/2$ lens is used with a plate one-half inch thick, all of the rays which reach the screen from points on the film can be accounted for only if we imagine the points

on the film extended to a considerable size. The plane parallel plate, in other words, is producing virtual images of the points and makes them appear to the lens as disks or streaks. Fig. 19 shows the major axis of the confusion disks for different points on the film and for different angular positions of a one-half inch plate. It will be noted that when the plate is tilted, the position of best apparent definition on the film shifts. It is, of course, impossible to correct the lens by any

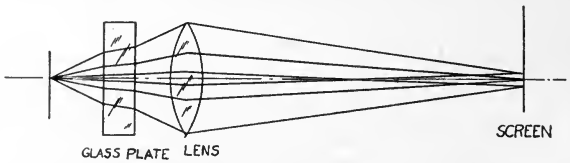


FIG. 17. The circle of confusion on the screen produced by the spherical aberration of a plane parallel plate on the short optical side of the projection lens.

stationary means for this varying astigmatic effect. The use of a similar moving plate on the image side of a one-to-one system might seem at first to offer a chance for correcting the defect, but unfortunately both spherical aberration and astigmatism in such a system are additive. Probably the best the optical designer can do is to correct the system for spherical aberration when the plate is normal.

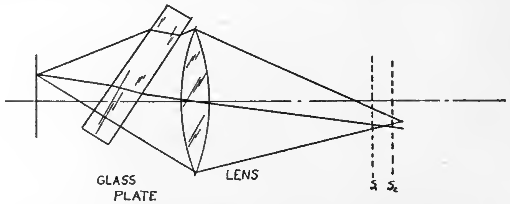


FIG. 18. Blurred image on the screen produced by a tilted plane parallel plate on the short optical side of the projection lens.

It may be advantageous to use a long focal length lens when a tilting plate is used. With a long focal length lens the definition is more uniform over the area considered because the film frame subtends a much smaller angle at the lens. It is not always advantageous to do this, however. The dotted curve shown in Fig. 19 shows the major axis of confusion disks for a 10-inch $f/2$ lens when a one-half inch plate is tilted at 10 degrees. Comparison of the definition obtained

in this manner with that obtained with a one-half inch plate tilted at 10 degrees with the 2-inch $f/2$ lens shows that we do not gain in definition until we get some distance below the axis or considerably above the axis.

The size of the astigmatic image is very materially reduced if the aperture of the lens is limited in the vertical dimension. We have to consider only a small pencil of rays passing through the plate. There

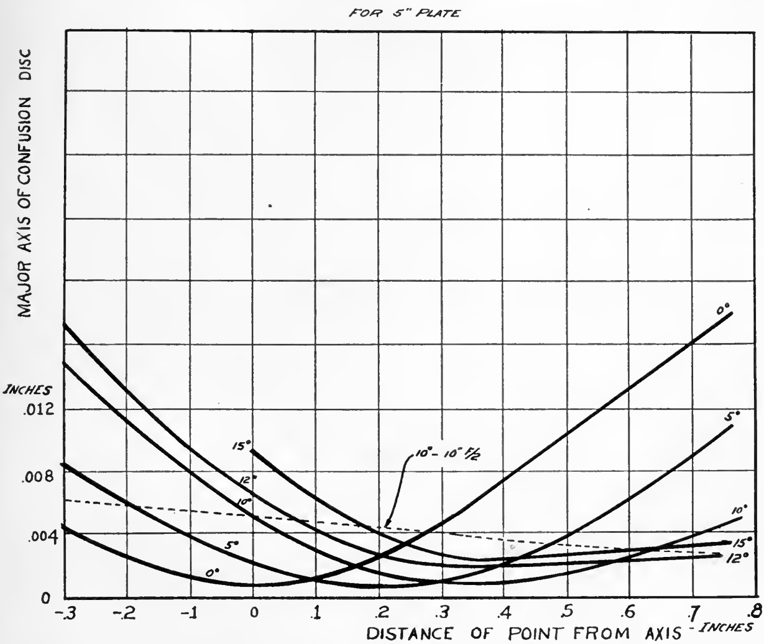


FIG. 19. The magnitude of the major axis of confusion disk caused by a one-half inch plane parallel glass plate in conjunction with a 2 inch $f/2$ projection lens as a function of the distance of the object point off the axis for different tilts of the plate. The dotted curve refers to a 10 inch $f/2$ lens with the plate tilted at 10 degrees.

are two unfortunate things about limiting this vertical angle, however: one, considerable light is lost and, two, it does not rid us of the distortion effect which is present with a tilted plate. Fig. 20 shows diagrammatically how this distortion is produced.

Under certain conditions the distortion effect may be improved by using two plates, each of half the original single-plate thickness, placed one on each side of a one-to-one optical system, as in Fig. 21.

When the plates are normal to the optic axis there is no distortion. When the plates are tilted, the distortion is somewhat corrected.

If we are willing to use a cam to oscillate the plate and a long focal length lens with a restricted vertical aperture, we can have theoretically good projection with a single plate tilting in the beam. The

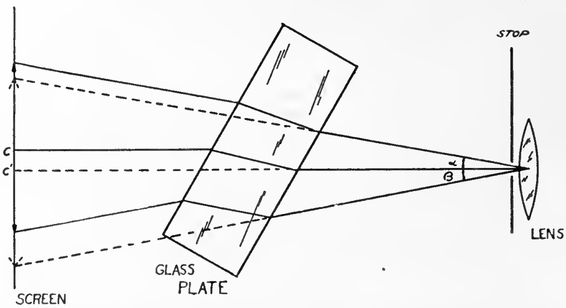


FIG. 20. Distortion produced by a plane parallel plate on the short optical side of the projection lens.

screen picture, however, would be small unless we relay the image. The loss of light in such a system, especially with the relay and with a shutter which would cover the return of the plate and have flicker blades, would rule out such a projector.

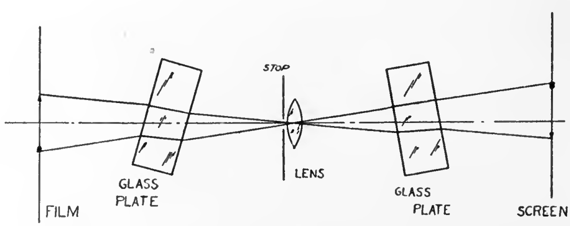


FIG. 21. The partial correction of the distortion produced by a plane parallel plate by the use of two similar plates on opposite sides of a lens working at unit magnification.

If we want to follow the film with uniformly rotating plates, we find in Fig. 22 that we will have to use a plate 3 inches thick, even for following 16-mm. film over the displacement of plus or minus half a frame, if we are to stay within our steadiness tolerance of 0.0005 inch. We can rotate this plate through an angle of only 8 degrees and

since we will have to have another plate ready to follow the next frame, we will have to have 48 plates arranged on a drum. Such a projector would be quite impracticable.

A very ingenious use of parallel plates can be found in one projector. By arranging plates as shown in Fig. 23 with the plates making an angle with their axis of rotation, but normal to the optical axis in their mid-position, it is possible to have the vertical com-

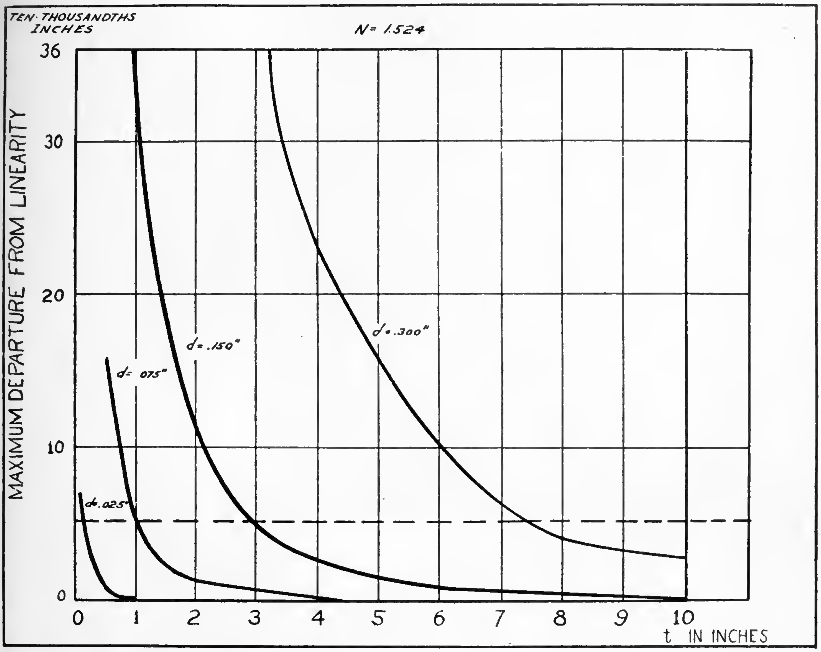


FIG. 22. The departure from a linear relation between the displacement produced by a plane parallel plate and the angle of tilt with respect to plate thickness, for various total displacements.

ponent of the displacement produced very nearly linear with the angle of rotation. The undesired horizontal component of the displacement can be compensated for by having other plates rotating in the same manner some place in the system in such a way that the vertical displacements are additive and the horizontal displacements offset one another. With this arrangement it is still necessary, however, to restrict the vertical angles subtended by the lens to get rid of astigmatism.

### MOVING MIRRORS

Plane reflecting surfaces can be used in the beam without producing any defects in the image. The single tilting mirror, however, can not be used alone without distorting the image. The method used for moving reflecting elements also introduces errors in the image.

In Fig. 24 there is shown a reflecting mirror tilted in the long

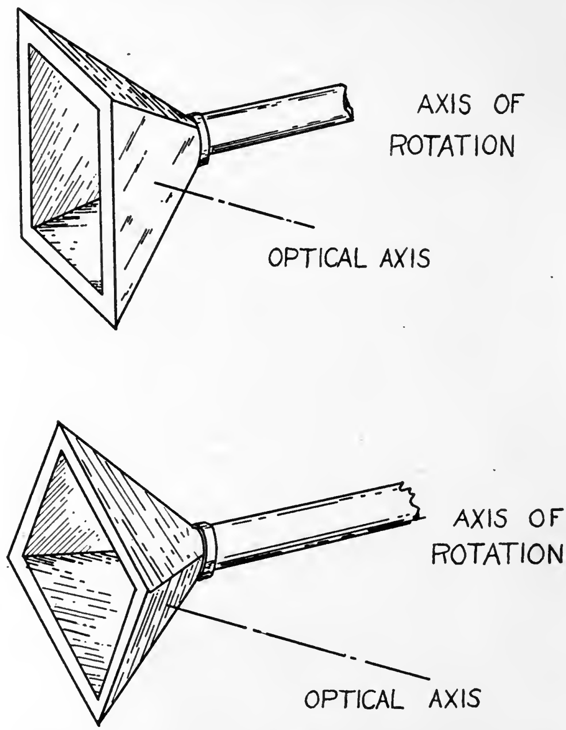


FIG. 23. A special method of tilting plane parallel plates to produce a good approximation to a linear relation between the vertical component of the displacement and the angular displacement about the axis of rotation of the plates.

optical side of a projection system. When the mirror is at 45 degrees the plane of the image formed by the system makes an angle of 90 degrees with the plane of the film gate. If the mirror is tilted through an angle sufficient to place the center of the frame, which is entirely above the axis of the lens on the center of the screen, the plane of the image does not correspond with the plane of the screen but falls along

the dotted line shown in Fig. 24. The image is rectilinear in its plane but, of course, is not projected on to the screen plane as a rectilinear image, nor is it exactly in focus. Because the image plane does not correspond to the screen plane, the screen image is distorted in two directions. Vertical lines on the film will not be parallel, the top edge of the picture being either narrower or wider than the bottom edge of the picture. Horizontal lines on the picture will be imaged as parallel lines on the screen, but horizontal lines equally spaced on the film will not be equally spaced on the screen. If the angle through which the mirror has to be tilted to keep the center of

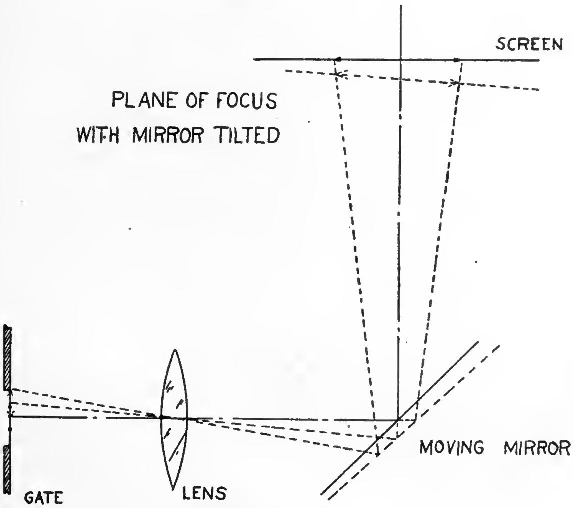


FIG. 24. Optical compensation for the film motion produced by a tilting mirror in the light path.

the frame imaged on the center of the screen is small, this keystoning distortion will not be serious. Hence, with a long focal length lens we will be able to tilt the mirror by some cam mechanism and have a satisfactory picture on the screen. If we want to avoid the use of cams and change the angle of tilt of the mirror linearly with time, we can mount a series of mirrors on the periphery of a drum and rotate the drum with uniform angular velocity. This sort of system of moving the mirrors, however, will affect the steadiness of the center point of the picture on the screen. If we use a straight gate and the film is moving at a constant linear speed through this gate, it is the

tangent of the angle which the center of the frame subtends at the lens from the axis of the lens, which is going to vary linearly with time and not the angle itself. Mr. H. Dennis Taylor in a paper published in *The Photographic Journal*, February, 1924, has shown that to get satisfactory projection with a system using a uniformly rotating drum of mirrors with 35-mm. film, it is necessary to use about 60 mirrors in the drum. The possible ways that have been proposed for reducing the defects produced in the image by a tilting mirror have involved the use of curved gates and toroidal lenses. We feel

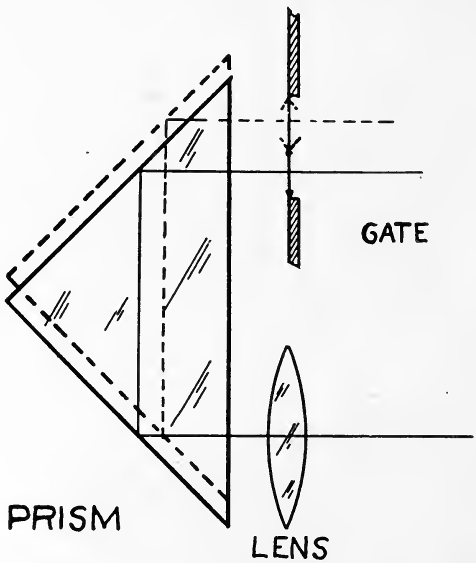


FIG. 25. A method of following moving film by the motion of a prism reflector.

certain that a curved gate could be used to correct to some extent for the distortion in the image. A very satisfactory projector has been designed which uses a series of cam actuated mirrors and a curved gate. A discussion of nonrectilinear lenses is beyond the scope of this paper.

Fig. 25 shows how two reflecting surfaces can be moved together and keep the image from moving film stationary on the screen. In this figure the reflecting surfaces are two faces of a right angle prism. It is evident that the mechanical problem of moving a series of prisms of this form at a constant linear speed and in a straight path in front of

the gate is difficult. The correcting element occupies considerable space, and it is difficult to have a second element ready to follow a second frame past the gate as soon as the first frame reaches the bottom of the gate. Further, the size of the prism is considerable and the back focus of the projection lens has to be long.

In Fig. 26 we have shown how reflecting surfaces of rhomb prisms may be moved to give a vertical optical displacement of the image. A single rhomb gives a parallel displacement to light which is equal to the face of the rhomb. If the rhomb is held in one position in the projection system, this displacement is all a vertical displacement.

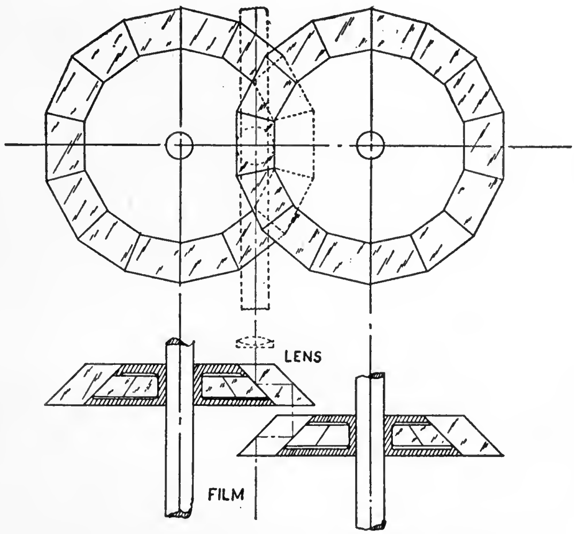


FIG. 26. The use of pairs of reflecting rhombs to produce a stationary image from moving film.

If the rhomb is rotated through 90 degrees, the vertical displacement is zero, the whole displacement being horizontal. Horizontal displacements of course are not desired in a non-intermittent projector. The figure shows how two rhombs may be rotated together in such a manner that the horizontal displacement of the image is zero and still allow a vertical displacement. If the wheels carrying the rhombs are rotated with uniform angular velocity, the displacement effected by the system varies not linearly but sinusoidally with time. Here again, then, we see that we will have to use a large number of rhombs to get satisfactory projection. We would like to point out that the

REFERENCE TABLE

| Means Used | Flicker | Amount of Light | Precision Requirements | Number of Matched Optical Parts Required | Remarks |
|---|---|---|---|---|---|
| Reciprocating lens. | Quick return covered by shutter. Flicker blades necessary. | Might equal intermittent projectors. | Lens must be positioned during projection to within $\pm 1/1500$ of its total movement for 35-mm. film. | One. | Large mass in reciprocating part. |
| Series of lenses in restricted path. | Light not constant during change-over period. | Possible to get $f/2$. Diaphragm or shutter probably necessary. | As above. Probably harder to fulfill. | Determined by mechanical means used. Probably six or more. | Projector likely to be noisy and cumbersome. |
| Lenses moving with uniform circular motion. | As above. | As above. | Considerable precision required in initial adjustment and matching of parts. Accurate gears. | Twelve. Preferably more. | A projector using lenses in this manner can be made to give satisfactory results. |
| Uniformly rotating series of plates with normals to plates in a plane. | Practically no light to screen during change-over. Flicker shutter necessary. | Lens aperture limited because of astigmatism. | Not difficult to meet. Accurate gears. | Forty-eight (for 16-mm. film). | Impractical. |
| Uniformly rotating plates with normals describing a cone. | As above. | As above. | Not difficult to meet. | Four or more (for 16-mm. film). | Such a projector can be made to give satisfactory results, but is a little short on amount of light. |

REFERENCE TABLE (*Cont'd*)

| Means Used | Flicker | Amount of Light | Precision Requirements | Number of Matched Optical Parts Required | Remarks |
|---|---|---|---|---|---|
| Uniformly rotating warped refracting elements. | Change-over can be very short. | Probably could be greater than intermittent projector light. | Elements very difficult to make, especially if they are achromatized. | One or several. | The longer the focal length of lens, the better the image. |
| Cam reciprocated mirrors. | With series of mirrors change-over period is short. | Might gain over intermittent machine. | Cams must control angular position of mirrors to within 1/1500 total angular movement. | Determined by mechanical means used. Eight satisfactory. | A projector of this type, the Mechau, has been built by Leitz and sold commercially. |
| Uniformly rotating drum of mirrors. | As above. | As above. | Accurate initial adjustment and gearing. | About sixty. | Most working models have had too few mirrors. |
| Rotating rhombs. | As above. | As above. | Rather difficult to fulfill. Accurate gears. | Sixteen or more. | This type can give satisfactory results. Long back focus required. |

path between the film and the lens is very long and we will have to use a long back focus lens for projecting with this system.

### SKEWED IMAGE-FORMING REFRACTING OR REFLECTING ELEMENTS

A number of inventors have proposed the use of spiral image-forming refracting or reflecting elements. These elements, of course, would be very difficult to make. Their only advantage would likely be in the fact that they would simplify the problems of moving the optical part in the beam. Their use would probably introduce a twisting distortion in the image.

### SUMMARY

We know that the four types of elements—lenses, prisms, plates, and mirrors—can be used under proper conditions to produce satisfactory pictures as far as quality is concerned. The projected picture is steady enough, free enough from distortion, and the definition is passable. It is possible to have the number of glass-air surfaces small enough so that the picture is not made flat because of flare. In some cases we have found that the focal length of the lens has to be longer than desirable, and we might have to use a relay system for getting the image large enough on the screen. These relay systems would introduce additional surfaces which certainly may lose a considerable amount of light. In some cases we found that to get a satisfactory picture we had to limit the *f* aperture of the projection lens. This, of course, will cut down on light. We have not discussed very fully the problem of keeping the light constant to the screen during the period which we use to change over from projecting from one frame to projecting from the successive frame. Any method we use, however, is very likely to limit the light to some part of the picture during the change-over period. With moving lenses there will be some barrel cutting and some loss of light from points which are considerably off the axis of the lens. With prisms we can not change suddenly from a prism base side up to a prism base side down without covering up the period of that change. Plane parallel plates joined together so as to pass successively in front of the gate will have a dividing line between plates, which appears to the film, because of refraction, to have considerable width. Even mirrors can hardly be joined together so that the dividing line between them is fine enough not to affect the light to the screen. Any change in the amount of light to the screen during the projection period demands the use of a shutter and flicker blades or some fixed diaphragm which will keep

the light constant. Either method will lose light to the screen. Many of the systems require a moving condenser system to get even illumination.

The precision requirements on the mechanical parts used in a non-intermittent projector can be computed by finding the angle or distance through which we can move the optical elements with the film stationary without shifting the image on the screen in an objectionable amount. The pitch of the sprocket must be equal to the pitch of the film to within 0.0005 inch in one perforation pitch if we are going to project the picture continuously and keep that picture steady on the screen. It may be necessary to have the optical elements used precisely matched, and the initial adjustment of the elements precisely made. These precision requirements, of course, will add to the cost of producing the projector.

If we are going to gain in quietness of the projector, we can not rapidly reciprocate parts which have considerable mass or moments of inertia. We can gain in quietness, however, if the projector design allows us to move all parts with constant angular velocity and have all parts counterbalanced. Many of the systems proposed impose special limitations on the projector. For some of them to work satisfactorily they would have to have ridiculous physical dimensions. Some of them demand a fixed screen distance or a variable focal length auxiliary projection lens. Some of them demand a special arrangement of pictures on the film. Several do not provide any framing for the picture except at the screen. Very few of them could be considered as projectors for projecting lenticulated color film.

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# WIDE SCREEN PHOTOGRAPHY WITH CYLINDRICAL ANAMORPHOSING SYSTEMS

## AND

# CHARACTERISTICS OF MOTION PICTURE LENSES AND IMAGES*

H. SIDNEY NEWCOMER**

***Summary.***—*This paper presents a brief description of the advantages of optical compression for producing wide screen pictures. There is included an exposition of the design and operating characteristics of cylindrical compression objectives, with particular reference to the high degree of central and marginal definition attainable. This latter is compared with the performance of existing motion picture lenses. In this connection there is presented a detailed quantitative description of the definition attainable with high-grade motion picture lenses. These data are correlated with information as to the physiological requirements for satisfactory definition on the screen.*

### INTRODUCTION

All lenses of whatever nature fall short of producing perfectly sharp images. Satisfactory motion pictures are possible because in the conditions under which the pictures are observed the eye does not readily detect imperfections that are below a certain level. The choice of any method of producing wide screen pictures will depend to a considerable extent on the possibility of obtaining images of suitable quality. If a method that produces suitable images be also economical and easy to apply, the combination is ideal. If the method be neither economical nor optically satisfactory, it has little to recommend it.

In order to form an intelligent opinion about the relative merits of different methods of producing wide screen pictures, one must have certain precise information about the definition that is obtained with motion picture lenses on standard film and how this definition is influenced; in the one case by optical compression with cylindrical lenses, and in the other case by increasing the width of the film and

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the area to be sharply covered by the lens. It is from this point of view that the subject is here presented.

This paper presents a brief description of the design and operating characteristics of cylindrical compression objectives together with an account of their advantages and performance possibilities when used to produce wide screen pictures on standard motion picture film. The subject is presented both from the point of view of the performance of existing lenses and of the mathematical and physiological considerations fixing the optimum quality of projected images. It is shown that all the better motion picture lenses approach a quality that is little more than sufficient to meet modern theater requirements.

The central portions of the picture are naturally subjected to the closest scrutiny, and there the best definition attainable is almost twice what the critical observer requires. On the other hand, the peripheral portions of the image are much worse, being subjected to a number of deteriorating influences that appreciably increase as the border of the present image frame is reached and passed.

## OPTICAL ADVANTAGES OF STANDARD FILM

Thus, from an optical point of view, standard film has many advantages, and the importance of the dimensions of the frame in forming suitably sharp images becomes apparent only after one has had an opportunity to study the performance characteristics of motion picture lenses. This not only has an important bearing on the dimensional relations obtaining in present-day practice, but it very seriously handicaps the use of wide film and affords a considerable advantage to optical compression as a means of obtaining laterally extended screen images.

Thus, from the point of view of sharpness of image, the results attained by the compression or anamorphosing objective are superior to those afforded by wide film. This advantage is by no means the sole merit of the method. The anamorphoser comes into play only twice in the entire sequence of operations from the taking of the picture to its projection on the screen; namely, at the beginning, when it is placed in front of the ordinary camera equipment used to take the picture, and at the end, when it is placed in front of the projector to expand the picture on the screen. In all the many stages of processing and handling, the film is treated as ordinary standard film, and the tremendous expense involved in providing

special equipment for processing, packaging, and projecting wide film is all avoided. The anamorphoser permits wide screen pictures of excellent quality to be shown interchangeably with standard pictures, and the method may be used for either whole features or particular scenes as desired. Contrary to current opinion it is extremely easy to mount cylindrical compression systems on both cameras and projectors.

### THE CYLINDRICAL COMPRESSION OBJECTIVE

In taking the picture, the effect of the anamorphoser is to compress a wide picture into a relatively narrow space. The compression is produced by a device that acts like an inverted telescope, but in one meridian only. The cylindrical anamorphoser is composed, in its simplest form, of a positive and a negative cylindrical member with axes parallel and arranged in the manner of an ordinary opera glass or Galilean telescope. The anamorphoser is afocal; hence its interposition in front of the ordinary camera or projection lens does not alter the focus of the lens. During the photographing, the anamorphoser merely compresses the image of the laterally extended scene into a narrow film space; during projection it expands the projected film image to an increased width on the screen.

The cylindrical anamorphoser is not a recent development, even in motion picture work. Ernest Abbé many years ago described all the types used today. At the beginning of the present motion picture era, Zollinger proposed to use them to compress the image and save expenditure for film. It was only recently, however, that serious attempts were made to rid these anamorphosers of the considerable color and other imagery defects which they exhibited and to correct them to the degree required in motion picture work. Many attempts at improving the photographic quality of these systems have not been very successful. Only a short time ago Mr. H. W. Lee, in speaking before the Royal Photographic Society, called attention to the fact that "the designing of these systems was exceedingly laborious, and the manufacture of deforming systems with cylindrical lenses far more difficult than of optical systems with spherical surfaces."

However, as is often the case, once a satisfactory solution has been obtained, the problem appears much simpler. As a matter of fact, if certain features of design be adhered to, features that involve among other things the relative indices of the glasses used and the orientation of the cemented surfaces and the cambrures of the ele-

ments, an extremely simple system that is unusually free from aberrations of every sort can be designed. Figs. 1 and 2 show, respectively, a photograph and a cross-section of a fully corrected anamorphoser, and serve to illustrate its simple and compact construction. This anamorphoser is used without any supplementary correcting system, none being necessary.

FIG. 1. Cylindrical anamorphoser: *left*, mounted in front of a 1-inch lens in company with a 2-inch and 4-inch lens on the same turret; *right*, on a bracket suspending it in front of any of three lenses on turret.

The aberrations of cylindrical systems of this sort are, in a way, analogous to those of spherical systems. In correcting for the imagery at the central portion of the field, once axial astigmatism is obviated by proper spacing arrangements, it remains only to rid the system of spherical and chromatic aberrations. This may be done by correcting each individual member separately. The residual

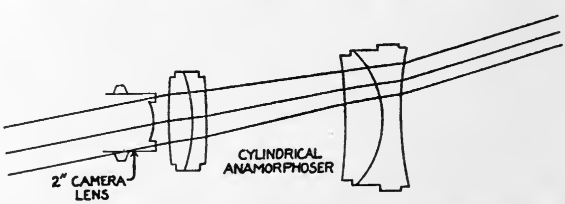


FIG. 2. A cross-section of a fully corrected anamorphoser.

secondary spectrum, and the zonal errors are then of similar magnitude and opposite sign, so that the assembled system may be exceptionally well corrected for axial image points. In fact, the writer has found that by thus largely ridding each member separately of spherical aberration, the zonal spherical aberrations of the system as a whole may indeed be made so small as to have a maximum value

of one part in thirty thousand, equivalent to a longitudinal focusing error of one part in one hundred and eighty thousand for an associated 50-mm. camera lens. The paraxial color focal difference in the spectral interval $C$ to $F$ may be one part in seven thousand and the zonal color differences one part in ten thousand, corresponding, respectively, to one part in forty thousand and one part in sixty thousand for the associated 50-mm. lens. These are, of course, fantastically and unnecessarily small errors.

### THE COLOR CORRECTION OF THE CYLINDRICAL OBJECTIVE

This leads us to a consideration of the color correction for marginal or extra-axial points of the image. The writer has found it possible by suitably constructing the two members, to eliminate astigmatism and coma along inclined rays; in other words, to make all the rays of any entering bundle of parallel rays traverse the objective and emerge from it still parallel. (See Fig. 2, and Fig. 3 at $C$.) This

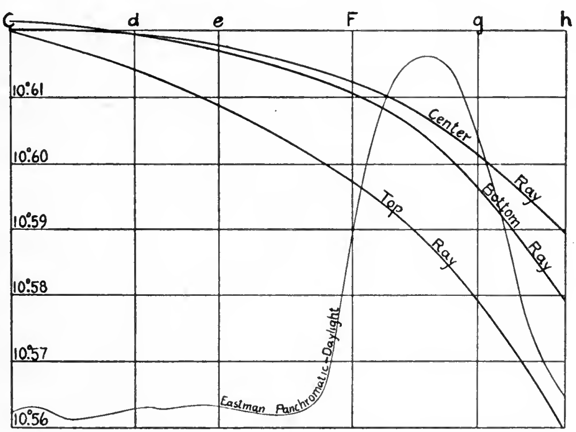


FIG. 3. Curves showing, for a certain anamorphoser, the angular spread of the three rays shown at the right in Fig. 2 when the rays at the left are parallel and at an angle of 7.05 degrees to the axis. Ordinates are angles with the axis.

parallelism can be made practically absolute for all the rays of a particular bundle, provided the light is monochromatic. But if the objective be composed, as just described, of members individually fully achromatized in the usual manner so as to be, as far as possible, free of color focal differences along the axis, there remains an appreciable lack of parallelism of the different colored rays of an in-

clined bundle, and hence a color fringe in the marginal areas of the picture. Fig. 3 illustrates the extent of such an error for a beam of parallel rays inclined 7 degrees on the camera side. The abscissas of Fig. 3 are wavelengths, designated by the conventional letters, and the ordinates are the angles of emergence with respect to the axis. Only the emergence angles for the central and two outside

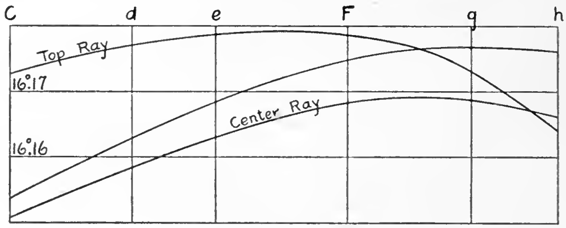


FIG. 4. Same as Fig. 3, but referring to an anamorphoser specially corrected to improve or narrow the color dispersion in the region $e$ to $h$.

rays of such a beam are plotted. (See also Fig. 2.) The maximum entrance height on the positive member as plotted is 1/20 the focal length of the member. This corresponds to a 15-mm. half-opening on the objective used in the demonstration, half its maximum open-

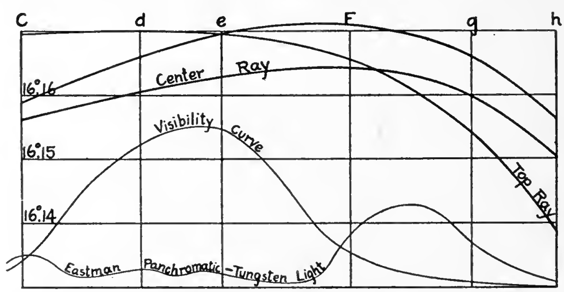


FIG. 5. Same as Fig. 3, but referring to an anamorphoser specially corrected to improve or narrow the color dispersion in the region $C$ to $g$, where visibility and Mazda lighting are most effective.

ing. Fig. 2 shows the position of such a ray with respect to an associated $f/2.3$ 50-mm. camera lens.

The curves of Fig. 3 show an angular emergence difference for the spectral interval $C$ to $h$ of 0.06 degree, corresponding to a diffusion circle of 0.035 millimeter for an associated 50-mm. camera lens, the angle being two-thirds as large on that side. At an inclination of

10.5 degrees, that is, for a point near the margin of the picture, the difference is greater, and the diffusion circle is about 0.06 millimeter in diameter. Although the actual effective error is somewhat less than this, nevertheless it is added to the relatively poor marginal performance of the camera and projection lenses, and therefore must be reduced.

There is an unusual and interesting method of eliminating this large marginal color error, namely, by only partially achromatizing each of the two members of the anamorphoser. Fig. 4 gives the curves for a 10.5-degree angle for an anamorphoser thus corrected, in this instance in such fashion as to reduce the angular difference, $F$ to $h$, to about 0.01 degree at a fractionally smaller opening. The operating characteristics of this anamorphoser are obviously excellent when used for photography in daylight with either ordinary or panchromatic stock. The marginal diffusion circle of the 50-mm. camera lens caused by the anamorphoser is only 0.006 millimeter.

Fig. 5 represents a slightly lesser degree of primary underachromatization, the purpose of which is to bring the maximum marginal correction into the spectral region $C$ to $g$. This anamorphoser gives optimum results, either for projection or for studio photography. In projection, although the absolute aperture is larger, the angle is less, so that the curves are not much different.

For convenience in interpreting the significance of the color corrections, there is drawn on Fig. 3 a sensitivity curve of Eastman panchromatic emulsion. The curve is drawn to an arithmetical scale, and not a logarithmic scale as is usually the case. The ordinates are estimated from readings of wedge spectra, the curve being then corrected by integrating various color regions and adjusting the curve so that the integrals correspond to the respective published exposure times.

In Fig. 5 are plotted a visibility curve and a sensitivity curve for Mazda illumination. The sensitivity curve is derived from the curve of Fig. 3 by multiplying the ordinates of Fig. 3 by the corresponding ordinates of a tungsten filament emission curve and dividing by those for daylight energy distribution. The abscissas of Figs. 3, 4, and 5, representing wavelengths, are drawn to logarithmic scale.

### ERRORS OF CYLINDRICAL OBJECTIVE COMPARED WITH THOSE OF CAMERA LENSES

Despite the existence of only a partial achromatization along the axis of each of the two members, the objective as a whole yet has a

very satisfactory paraxial and spherical color correction, one part in seven hundred and one in a thousand, respectively. The resulting diffusion circles for an associated 50-mm. camera lens are less than 0.002 millimeter in diameter, a value that, as will be seen, is too small to produce any deteriorating effect on the quality of a motion picture image. These figures (increased by 50 per cent for good measure) for the diffusion circles at the center and margin of standard film due to the anamorphoser are plotted in Fig. 7, where they may be compared with the much greater diffusion of the image resulting from the defects of the camera lens itself.

Since the anamorphoser is afocal, its relative opening depends only on its absolute size. It is, in fact, convenient to choose the size so as to reduce the aberrations considerably below those of the spherical objective with which the anamorphoser is associated. The anamorphoser has, therefore, an almost negligible deteriorating effect upon the image. In fact, the very slight effect observed must be attributed almost entirely to the interposition of the four air-to-glass refracting surfaces. It amounts at the most to a difference of one stop; and since motion picture lenses are now available that are appreciably more than this amount superior to most motion picture lenses now in common use, it will be obvious that one can obtain all the advantages of the anamorphoser for the production of wide screen pictures and yet retain the quality of picture to which the critical observer is now accustomed.

Except for the slight effect of surface loss, the anamorphoser does not increase the required exposure time. On projection, there is a light loss due to the expansion, and which is proportional to the expansion. We have experimented until we can print anamorphosed film so that the projected image appears as brilliant as ordinary screen images. Before this result was accomplished, it was found possible and practicable to increase the arc current until anamorphosed and ordinary illumination of the screen, projected consecutively from different machines, appeared equally brilliant. The Scott Parrish single blade superspeed shutter passing about 50 per cent more light without flicker by decreasing the occulting time, and readily adaptable as it is to existing projectors, should put an end to any necessity of increasing light.

The cylindrical anamorphoser consists of a positive and a negative member so spaced as to give an afocal combination. The axes of the cylinders are parallel; in fact strict parallelism is essential.

The allowable errors in alignment are almost infinitesimal, but mechanical and optical means for rapidly attaining and maintaining suitable alignment have been devised, and have solved what at first seemed to be an insuperable obstacle to the development of a good objective. Similarly, means have been found of grinding and polishing cylindrical surfaces so that they can be made as easily as spherical surfaces and, as with the latter, to any degree of perfection that seems necessary and desirable. Their manufacture is not in any sense a hand process. The quality improves when the lenses are made in series.

### FACTORS DETERMINING THE QUALITY OF THE ORDINARY MOTION PICTURE IMAGE

Present-day motion picture photography and projection make demands on the optical equipment that can be properly understood only when three independent stages of the image-reproducing process are analysed and subjected to quantitative measurement and interpretation. Thus we have first to consider the quality of the image on the negative film, an image that is carried essentially unchanged to the positive film. Then the image must be projected by means of an optical system that has, as we shall see, certain inherent limitations. Lastly, the eye perceives the screen image and requires, for a subjective sensation of sharpness and brilliance, that the blurring of the details of the image shall not exceed amounts that we shall later discuss and correlate with the definition obtainable. As the first step we shall consider the photographic image.

### THE NEGATIVE MOTION PICTURE IMAGE

Practical studio lighting conditions and emulsion speeds require the use of relatively large aperture lenses, between $f/2$ and $f/3$. This means that the apex of the cone of light forming a point image on the film embraces a rather large angle, and when not focused on the film casts thereon a circle of diffused light of appreciable size, a size also proportionate to the distance of the apex of the cone from the film. In order, therefore, that there may be a reasonable depth of focus and sharpness of image, the focal length of the lens must be short. This necessity is not avoided by using larger film.

The average focal length used for general purposes is 50-mm. or 2 inches. Shorter focal lengths are frequently used, for instance $1^3/_8$ inches; but the ability of most lenses to cover a 1-inch field at a 20 degree semiangular opening with sufficient sharpness is partly due to the absolute decrease in the dimensions of the marginal imagery

errors. A 2-inch lens covering a 1-inch field has a semiangular opening of 14 degrees. A discussion of the characteristics of the images formed by such lenses will serve to set forth the conditions under which motion picture lenses operate.

### TYPES OF MOTION PICTURE LENSES

It has not been an easy problem to design lenses that will give satisfactory results under the conditions obtaining in motion picture photography. W. Merté[1] discusses briefly the difficulties with which the designer of such objectives is faced. One of the methods of approach to the problem is to modify the Petzval objective so as to flatten its field. As is well known, this objective in its original form has a large aperture and an unusually sharp central definition for a lens of such simple construction. The definition, however, rapidly falls off and is unsatisfactory even for short focal lengths at the margin of a field subtending a greater semiangular opening than about 7 degrees, requiring thus a 4-inch lens to cover a standard frame. (See Fig. 6, *Solex* and *Cinephor*.)

A second modification is obtained by placing a strong collective element in front of or behind suitably designed Taylor triplets. See, for instance, the *Ernostar* (Merté No. 10/8) and the *Astro-Tachar* (Merté No. 11/8).

A third modification, semisymmetrical in type, is based on the old Rudolph Planar which, in turn, was developed after Alvan Clark's lens of 1889 (U. S. Pat. No. 399,499). Each half has a strong collective element in front of a compound dispersive element. Examples of this are seen in the *Xenon, Raytar, Biotar* (Merté No. 14/8) and the *Makro-Plasmat.*

Another type is derived from a symmetrical lens by introducing into each half a dispersive meniscus turned convex toward the diaphragm (Merté No. 7/8). Such lenses having large apertures have been widely used for amateur photography, but they cover only a small field and show considerable spherical aberration.

Another class of objectives deserving mention are those triplets that have been redesigned to increase the opening to $f/3.5$ or more. Examples are the *Hypar* (similar to Merté No. 11/3) and, particularly because of its wide angle, the *Tessar* (Merté Nos. 12/4, 13/4).

The quality and suitability of any of these lenses is in part dependent upon the curvatures of their focal surfaces, their spherical aberrations and their sine condition errors. All these characteristics,

for a great many lenses, are individually set forth in graphic form in Merté's work above referred to. Whereas the graphs for the various lenses show differences that must be associated with variations in their image-forming characteristics, these differences, as between the more important examples, are of less significance to lens performance than other features more readily recognized on direct examination.

In order to bring out the limitations of all these lenses and to show to what extent they are being utilized to their maximum capacity, a short description of their individual and relative performance characteristics may be made.

### QUANTITATIVE ANALYSIS OF MOTION PICTURE LENS IMAGES

Figs. 6 and 7 show two sets of curves illustrating the operating characteristics of a number of the more important motion picture lenses. Fig. 6 shows the form of the two focal surfaces, tangential and sagittal as they are called, of four photographic lenses and four projection lenses. These measurements were made on a suitable optical bench with a cross slide, using a simple ocular to locate, on a finely ground glass mounted on a vernier slide, the best focus for tangential and radial (sagittal) lines of the target, at different angles of the target away from and at right angles to the axis of the lens. In the case of the camera lenses, 2- or 3-inch lenses were used for the measurements. The curves show where, with respect to the focal plane, the best focus for the two sets of lines is obtained. The sagittal surface generally lies nearer the lens. In the illustration, in each instance, the respective surfaces are indicated by the letters $S$ and $T$. The unit "one" is chosen as one one-hundredth part of the focal length. A certain approximation of the two curves to each other and to the focal plane is necessary for good definition, but the existence of such an approximation does not, unfortunately, necessarily mean that there is good definition. Thus, on the one hand, the quality of the image on the surface may be poor; or, on the other hand, there may be a fairly good image at some distance from the surface. A comparison of the curves of Fig. 6 with those for blurring of the image (Fig. 7) will show a correlation between the two, but the latter curves more accurately indicate the quality of the image on the film.

Fig. 7 plots for each lens described the approximate blurring of the image, or the size of the diffusion circle in hundredths of a millimeter

for 50-mm. lenses, $f/2.3$ opening (except *Tessar* $f/2.7$) at various semiangular fields. The sizes of the diffusion circles are estimated from inspection, under suitable magnification, of images of bold-faced type on fine-grain negatives. In general, a block-faced letter must be a little over $2^1/_2$ times the height of the estimated diffusion circle to be legible, although words are legible at somewhat less height. Illegibility may be due to a number of imagery defects. Thus, there may be mostly simple diffusion of the image as with the

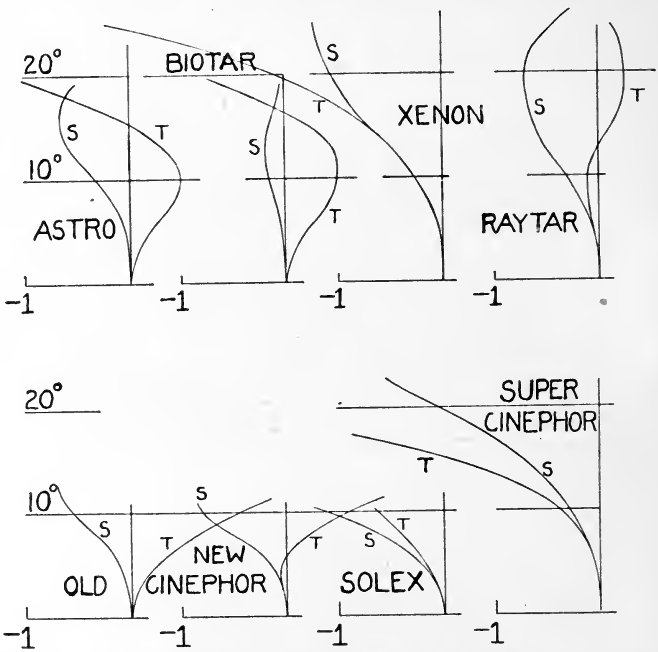


FIG. 6. Sagittal and tangential focal surfaces of four motion picture camera lenses and four projection lenses. Ordinates are semiangular field; abscissas $^1/_{100}$ focal length.

*Xenon* or *Raytar;* or marked astigmatism may account for the illegibility, as in the case of the *Biotar* and *Tessar* intermediate zone deterioration.

The curves of Fig. 7 serve to help one to visualize the more particular description of the following paragraphs, and also to correlate information contained therein with the conditions obtaining on projection of the image on the screen, a problem to be discussed later.

The following information is based on the microscopic examination of fine-grain Eastman No. 40 and Wratten and Wainwright panchromatic emulsion test chart plates, Mazda lighting, using posterior and anterior targets to control the focal plane setting of 2-inch lenses. Valuable additional information was obtained by the direct microscopic examination of free aerial images using microscope objectives of sufficient aperture to take in the entire cone of light traversing the lens aperture and forming the image. This latter method enables

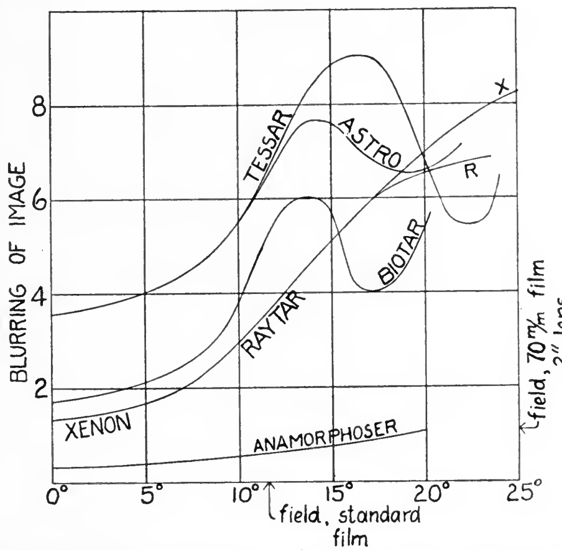


FIG. 7. Curves for five 2-inch motion picture lenses and for the corresponding maximum increment of diffusion due to the simultaneous use of an anamorphoser of the type described. The lateral edges of the image fields of standard and wide film are indicated. Ordinates are diffusion circles in $^1/_{100}$-mm.; standard as described.

one instantly to appraise the image quality and to determine absolutely the performance characteristics at the center of the field and the performance possibilities for nonaxial points without, however, determining whether a good lateral image actually lies in the Gaussian plane. The method is, of course, most productive for those who are in the habit of critically examining microscope images.

The *Tessar f*/2.7 is an example of a large aperture lens with considerable covering power. The 50-mm. lens image is fairly sharp at the edge of a 44-mm. area, 24-degree semiangular field. At these

large openings, the definition of the central and intermediate areas is relatively much poorer than with certain other types of lenses. In fact, in an intermediate zone from $12^1/_2$ to 20 degrees there is a distinct astigmatic blurring of the image even at appreciably smaller openings. The images are slightly better on Eastman No. 40 emulsion than on panchromatic stock. As the *Tessar* is stopped down to $f/4.5$, it loses some of its relative superiority as a wide-angle lens. Thus, the *Xenon* gives a much sharper image everywhere up to about 20 degrees. The very slightly greater sharpness of the *Raytar* at large angles is a stopping-down effect accompanied by decreased illumination. With smaller stops ($f/4.5$) the sharpness of the marginal image increases and the illumination becomes more uniform.

At $f/2.7$ the *Xenon* is quite sharp for a central area of about 11 degrees semiangle; and at $f/3.2$ it has nearly reached the limit of resolving power of the emulsion, and leaves little room for further improvement. Even stopping it to $f/8$, for instance, extends this area of extreme sharpness only to 15 degrees, and without much change over $f/3.2$. The *Tessar* at $f/8$, while not so sharp in this region, is distinctly better to the edge of a much larger field, *i. e.*, beyond about 18 degrees.

The *Biotar* $f/1.4$ is one of the better wide aperture lenses, although it does not give images of the quality here under discussion until stopped down to apertures equivalent to those of other available lenses. At $f/2$ or $f/2.3$, the *Xenon* is somewhat sharper over the central area and is quite good to about 15 degrees, whereas the *Biotar* falls off much more rapidly beyond 10 degrees but improves again beyond 15 degrees to be better for a narrow peripheral zone. As the stop is decreased to $f/4.5$ and smaller, the *Biotar* maintains its wide angle superiority and becomes equal to the best lenses at the center. The *Biotar* gives slightly better images on No. 40 emulsion, but the difference does not amount to more than one stop ($f/2.3$ to $f/2.7$).

A further idea of the relative sharpness of the images of these lenses can be had by reference to Fig. 7. In this connection it should be noted that, for instance, the *Astro Pan-Tachar* $f/2.3$ is a very popular lens for motion picture work, perhaps because it lacks a certain degree of sharpness, even at the center, so that there is less difference across the field. The fields of both the *Biotar* and the *Astro Pan-Tachar* cut off sharply at about 22 degrees, whereas the *Makro-Plasmat* has a very wide field without, however, as good defini-

tion at the larger angles, beyond 6 degrees, as even the *Astro Pan-Tachar*. The *Makro-Plasmat,* when stopped down to $f/4.5$, has excellent central images up to about a 7-degree demiangular opening.

Both the new *Raytar* $f/2.3$ and the *Xenon* are representatives of a type of lens that permits the attainment of high speed with excellent definition. Good specimens of either lens in 50-mm. focal lengths and $f/2.3$ opening will image distinctly in the visible spectrum over a semiangular field of 5 degrees a one four-hundredth millimeter break in a black line of the same width. At 10 degrees, they have about one-half and at 15 degrees one-fifth this resolving power. At the center it is nearly twice as great. By way of comparison the resolving power in the central area of the *Astro Pan-Tachar* as viewed in the microscope is hardly one-third that of these lenses.

In this discussion of image quality, perfect definition as judged by the microscope corresponds closely to the maximum observed sharpness of the target image on the plate, and such pictures when projected with suitable lenses, even in large theaters, show extremely good definition. When the images are less sharp, the difference is noticeable on the screen; but if the lighting of the object is such as to give "brilliance" to the image, less sharp definition nevertheless gives perfectly satisfactory images. Thus the *Astro Pan-Tachar,* at $f/2.3$ with suitable lighting, gives brilliant images with, however, an observable deterioration toward the border to a critical eye.

## LIMITS OF THE IMAGE FIELD

The rate of deterioration of the images with angle is for many of these lenses such as to make the images unsatisfactory when the angle is more than 10 or 12 degrees unless the focus is very short. The maximum field satisfactorily covered by short focus wide aperture lenses is 22 degrees, (28 millimeters at a focal length of 35 millimeters), and then only with a certain loss of quality which is noticeable on projection if details are to be pictured.

When the focal length is increased to 50 millimeters, the standard movietone frame has a horizontal semiangular field of about $11^1/_2$ degrees, which is about the limit to which most lenses still give sufficiently good marginal definition not to detract from the quality of the picture. The best lenses will cover satisfactorily somewhat more than this, but even on the new 50-mm. wide film the angle is $5^1/_2$ degrees greater, and then the lenses available are either appreciably poorer at the border or show an intermediate zone of blurring.

The old 70-mm. wide film carries the field clear out to 25 degrees; and it is obvious from the data given here, as well as from practical experience with such film, that no lens covers this field with anything approaching the definition attained with standard film.

Thus, a careful study of the properties of the principal sharply imaging motion picture lenses not only shows their individual points of superiority and the absence of a "universal" lens, but makes it quite clear that definition to the degree now attained with standard film can not be attained on substantially larger areas if equal lens speeds are to be used. On the other hand, wider pictures can be optically compressed satisfactorily into the area in which good images are obtainable.

Several wide film pictures were shown in 1930. Opinions as to the sharpness of the images in these pictures vary with the interest and attention of the observer and with his skill in taking account of detail and contrast as they affect apparent definition. Clever composition and lighting play an important role in the appearance of such pictures. Certain of the wide film pictures shown were very objectionally lacking in portrayal of detail. They all showed distinct loss of definition in the outer portions of the picture.

It seems hardly necessary to mention here the very poor results obtainable when wide screen pictures are attempted when using reduced film images of modified shape blocked out on standard film. Here, as was amply demonstrated in 1930 and as could have been foreseen, projection difficulties are insurmountable.

## THE PROJECTION LENS, ITS THEORETICAL AND PRACTICAL LIMITATIONS

When it comes to projection the same or greater difficulties present themselves. The focal lengths are longer, 4 to 7 inches, and in order to obtain, with a suitable aperture, the required high degree of central definition needed for such long focal lengths, it is necessary to use lenses of the Petzval type having notoriously limited angular fields. The greatest volume of light is probably confined to an $f/3$ projection aperture, and with such an opening the central images of the best Petzval lenses are on direct visual examination somewhat less sharp but approximately the same as those of the motion picture lenses just described.

The actual sizes of the diffusion circles of the Petzval lens have been the subject of exhaustive mathematical analysis. In fact, it would not be proper to leave this subject without reference to the

classical paper by K. Schwarzschild on the astrophotographic objective.[2] Such an objective may be defined as one in which the area to be sharply covered is not greater than the diameter of the objective, a condition that holds in motion picture photography and projection with lenses of 3-inch focus and longer. Taking account of third order terms, Schwarzschild gives a complete mathematical analysis of the resolving powers of such lenses and evaluates the theoretical minimum attainable diffusion of their images.

As is well known, the expansions of expressions for the aberrations of spherical objectives contain only odd order terms, and it has not yet been possible to derive solutions in which fifth or higher order terms are retained. Probably such derivations are beyond the capacity of the human mind. They seem to be unnecessary when certain restrictions on aperture and curvature of glass surfaces are made.

The motion picture lenses of larger aperture, having, as some or all of them do, large curvatures of the glass surfaces, represent empirical solutions of the problem controlled by laborious trigonometric calculations. While generalizations should not be made, it is probable that the more or less uniformity in the marginal image defects shown by the best of these lenses is an expression of the minimal expectable residuum of third and fifth order aberrations. Thus, where large openings and a high degree of central definition are required, the further addition of surfaces has, as we have seen, reduced the aberrations outside the axis so as to extend the field slightly and at the same time give the advantage of increased openings with practical limits of about $f/2.3$. (Compare for instance, in Fig. 6, the first three lenses in the second line with the other lenses.)

Every useful objective must be achromatic, *i. e.*, color corrected for two particular wavelengths. The residual lack of color correction for the intervening wavelengths is called the secondary spectrum of the lens, and in the useful spectral interval reaches a maximum at a certain wavelength. This color error of the astrophotographic objective is for the center of the field the worst error that it has; and however small other errors may be, they will be hidden in the color diffusion circle. The latter, therefore, even if somewhat better tolerated, furnishes a criterion for the measurement of other errors. Schwarzschild has shown that this color error has a minimum theoretical value, which may be expressed in terms of the size of the resulting diffusion circle in the focal plane of the objective, this circle subtending an arc of $33'' \, v$, where $v$ is the diameter of the lens opening,

with a diameter of $f/10$ taken as unity. For a narrow spectral range, as in projection, this figure can be at least halved.

It is hardly necessary to mention that objectives comprised of thin unspaced glasses, as in telescopes, show considerable astigmatism and curvature of the image fields. In fact if $g$ represents the semi-angular opening of the image field, with 3 degrees taken as unity, then the two diameters of the diffusion circle of such lenses are $104'' g^2v$ and $47'' g^2v$, respectively.

By separation of the elements, curvature of the field and coma can be eliminated; and if one adheres to the Petzval type, the greatest theoretical reduction in the diffusion circle due to astigmatism is to $9'' g^2v$. When we come to build such lenses, $12'' g^2v$ seems to be the practical lower limit. The lenses have, however, the theoretical lower limit for the secondary spectrum, namely, $33''v$.

In Fig. 6 are shown the positions of the tangential and sagittal image surfaces of two types of Petzval lenses. The *Cinephor* was selected for this discussion because it is an example of the most common type of Petzval construction in projection lenses. It has considerable astigmatism, but the average curvature of the field is not far from zero. A drawing is included of a *Cinephor* of later manufacture having, up to nearly 5 degrees, no astigmatism and a very flat field. Another type is illustrated by the *Solex* lens. The *Solex,* although having an appreciable curvature of field beyond 5 degrees, up to that point has little curvature and less astigmatism and gives excellent images with standard film in the usual focal lengths.

In all instances curves for $4^1/_2$-inch projection lenses are given. In motion picture projection, the size of the field to be projected remains constant regardless of the focal length of the lens; hence the designers of projection lenses have been under no obligation to make all focal lengths geometrically similar, such as is generally done in the case of ordinary photographic lenses where plate size is proportional to focal length. The values given for the *Solex* and *Cinephor,* therefore, can not be regarded as strictly applicable to all lenses bearing those names, although they give a correct impression as to their characteristics. Likewise, the focal surface characteristics of certain motion picture camera lenses vary with the focal length.

The Taylor type of objective, with three spaced elements and somewhat greater curvatures of the glass surfaces, can be designed with appreciably smaller diffusion circles due to astigmatism, but the secondary spectrum increases to about $51''v$.

Let us now evaluate these expressions. A $4^1/_2$-inch projection lens has a horizontal semiangular field on movietone film of about 5 degrees. The useful opening is probably not over $f/3.3$. Thus $v$ is 3, $g$ is 1.67, $g^2$ is 2.8, and $g^2v$ is 8.4. The lens being of the Petzval type, its diffusion circle at the margin is about 100 seconds or 0.055 millimeter. Its color diffusion circle at the center is probably about $10''v$ or 0.017 millimeter. Both these figures correspond very well to the observed tolerances and direct observation on good lenses. The figure for the margin is usually a little larger.

The result of projection is then to deteriorate still further, but to an unimportant extent, the central image. The legibility of details in the projected image is within the tolerances to be discussed. The deterioration of the marginal image of the standard frame is of more consequence, but is still just allowable. If, however, a Petzval lens were used to cover the frame of 50-mm. wide film, $g^2$ becomes three times as large and the marginal diffusion circle is 0.165 millimeter. As we shall see, this is too large. To project such pictures, other lenses must be used. Unfortunately, it is not easy to find a substitute. The use of an anamorphoser is a much simpler solution.

### DEFINITION ON THE SCREEN; PHYSIOLOGICAL REQUIREMENTS CORRELATED WITH LENS PERFORMANCE

We should now consider these numerical data in the light of the observed image on the screen. The center of a sharp motion picture negative or positive will show distinctly letters formed by lines 0.01 to 0.02 millimeter wide. Letters that are 0.1 millimeter high on the film may be nearly illegible without one's noticing loss of detail when the picture is projected. In a theater with a 100-foot throw and a 25-foot picture, such a letter is about 30 millimeters high on the screen. At a distance of 40 feet from the screen, the average person with good vision can read letters 20 millimeters high, but he does not try to exercise his vision to this extent and can not distinguish the coarser details of the letters until they are about 80 millimeters high, the distinguishable details then having dimensions of about 10 millimeters.

Probably the average critical observer does not notice extreme haziness of letters that are 0.1 millimeter high on the film. Even their being illegible may not be noticed, so that what has here been called a 0.04-mm. diffusion circle would be just tolerated at the center of the picture. This size of diffusion circle would be quite satisfactory at the border, and nearly twice that size would be tolerated provided

projection did not make matters worse. The figure 0.055 millimeter given above for projection is perhaps not to be added in its entirety to the size of the diffusion circle at the margin of the negative image (Fig. 6) but the combined effect must be just about what has been considered allowable.

In order to visualize the meaning of these figures one might hold an inside page of the New York *Times* at arms length. The "want ads" will be just legible. The individual letters, even if jumbled, would also be legible if they were distinctly formed. Such letters correspond to the 20-mm. screen letters of the above example or to 0.07-mm. film letters. Even the very best lenses will not reproduce such characters sharply; and, indeed, the reader in looking over the newspaper at arms length does not attempt to notice print of that size. He is not even attentive to the ordinary newsprint, which is half again as large. On the other hand, letters 40 millimeters high on the screen—0.14 millimeter on the film, for which our diffusion circle is 0.05 millimeter—correspond to minor titles in the news column, which may very well be read if the attention be attracted to them. In sharp film they will be legible, but not as clear as in the news print analogy. The 80-mm. screen letters, appearing sharp or at least clear, as they do in good pictures, correspond roughly to the column headings in the newspaper. They must appear distinct if even the casual observer is to be satisfied. While such letters are sharp at the center and distinct to the edge of standard film, a comparison with the curves of Figs. 6 and 7 shows that they would be just about illegible in the peripheral areas of wide film no matter what lens were used.

Anamorphosed or compressed negative motion picture images are obtainable in actual practice in which there is perfect definition of letters appearing even at the margin of the picture and of sizes down to 0.14 millimeter high on the film. Such letters to be sharp mean diffusion circles appreciably less than 0.04 millimeter on the film. In practice, letters that are 0.04 millimeter high on the film are illegible, the amount of illegibility fixing the diffusion circles in the central area at about 0.02 millimeter, corresponding therefore with the data of Fig. 7.

Referring to Fig. 6, it should be remembered that the projection lens works at twice the focal length of the typical camera lens we have been considering. The diffusion referable to the curvature of the image fields shown for the *Solex* and *Cinephor* projection lenses

should be doubled when making comparisons with the data for the camera lenses. The projection lens, however, when used on standard film, is required to cover at most a semiangular field of only 5 degrees, and under such conditions does fairly well. It is extremely poor at 10 degrees and useless beyond and, indeed, before 10 degrees.

Where wide angle projection is necessary, it is possible to better the performance of the Petzval lens. Reference will not be made here to back screen projection where both the focal length and throw are short and the screen image less sharp than in standard practice. We have seen that attempts to improve lenses that perform similarly to the Petzval lens have resulted in the development of the present motion picture camera lenses. In the case of the best motion picture lenses above described, working at $f/2.3$ or $f/2.7$ for $4^1/_2$-inch focus, the diffusion circles at the center of the image for the visible spectrum are about 0.004 to 0.01 millimeter. Letters 0.05 millimeter high on the film are quite legible and sharp. On the other hand, at a semi-angular field of 8 or 10 degrees and for this focal length, the diffusion circles are about 0.04 millimeter or more.

The *Super Cinephor* is an example of a camera lens, the *Raytar*, adapted to projection purposes. In Fig. 6 are given the forms of its image surfaces. (The 6″ *Raytar* has similar but still more curved surfaces, particularly the sagittal surface.) There is a distinct flattening at the larger angles as compared with the Petzval type lenses.

By way of comparison, the hand camera anastigmat working at considerably smaller openings seeks to limit the diffusion at a semi-angular field of about 30 degrees to 120 seconds. The central definition is not as good as with the lenses here under discussion. Great skill and effort have been expended in an endeavor to improve the marginal definition of all of these lenses. The limits reached are fairly well defined and the underlying mathematical concepts do not offer much encouragement that the results already achieved will be much extended.

It has been shown that it is not possible to take, nor is it feasible to project, wide screen pictures under conditions that will result in images half as good as those now obtained. On the other hand, wide screen pictures of a quality comparable with the present standard pictures may be obtained by using an anamorphoser. The simplicity of this method of projecting wide screen pictures hardly needs to be elaborated upon. One further advantage of the anamorphoser should, however, be mentioned. This is an optical advantage.

increasing the depth of focus, and hence the general sharpness of the images, over and above that of ordinary pictures.

### THE CYLINDRICAL ANAMORPHOSER INCREASES DEPTH OF FOCUS

A cylindrical anamorphosing system magnifying 50 per cent in one meridian increases the depth of focus in that meridian by 100 per cent. If the anamorphoser be focused for a given object distance, then the interaction of the two elements of the anamorphoser on light coming from points nearer and further away is such as to approximate the corresponding camera lens images and bring them nearer the image plane for the mean focus. The amount they are moved toward this plane is exactly one-half the focusing difference for the camera lens.

For reasons associated with the nature of image formation in the eye, the effect of natural diagonal astigmatism, the apparent gain in depth of focus is practically equivalent to these figures. In fact, all who have studied anamorphosed wide screen pictures have noticed this effect. Similarly, for physiological reasons, the expansion in one meridian only does not increase the graininess of the projected image. The pictures are as smooth and free from graininess as unexpanded pictures two-thirds the size.

Up to this point we have considered only the quality of the image in the plane of best focus. Nothing has been said as to the loss of definition due to the photographing of portions of the object lying in front of or behind the plane of sharpest focus.

The following table gives the focal distances for a certain series of lenses when the object is at 15, 20, and 25 feet. The last two lines of the table give the focal differences with respect to the mean image for the 20-foot distant object.

*Focal Distances of a Lens Series*
*(Millimeters)*

| Object Distance (Feet) | 50 | 75 | 100 | 125 | 150 |
|---|---|---|---|---|---|
| 15 | 50.553 | 76.251 | 102.236 | 128.513 | 155.09 |
| 20 | 50.413 | 75.935 | 101.67 | 127.616 | 153.8 |
| 25 | 50.33 | 75.74 | 101.33 | 127.084 | 153.01 |
| diff. in | 0.14 | 0.316 | 0.57 | 0.897 | 1.29 |
| diff. out | 0.08 | 0.20 | 0.30 | 0.532 | 0.8 |

The relative openings being the same in each case, the sizes of the diffusion circles, due to distances out of focus, of the objects in front

and back of the sharply imaged object are directly proportional to these distances. Thus, if the focal length of the lens be doubled, the figures show that the loss of definition due to decreased depth of focus is increased four times.

Consider the deterioration of the image of a 50-mm. lens due to depth in the object, as given in the example. For the lesser of the two differences it amounts to a diffusion circle of 0.04 millimeter. Diffusion circles this large (and many are even larger) all over the film area cause the quality of the picture to deteriorate to an appreciable extent. The anamorphoser reduces these diffusion circles to half, and does much to improve the actual operating quality of the image and bring it within figures comparable with those given for the plane of best focus, as for instance in the data of Fig. 7.

For cameras, combination motion picture lens and anamorphoser mounts make focusing a single operation, as simple as in ordinary practice. For the theater, a simple fixed mount can be devised which reduces both costs and adjustments, and permits rough handling. Orientation of the anamorphoser in the proper meridian is so simple that any child could accomplish it.

Thus, the optical and practical advantages of the anamorphoser are real and important. Its use will greatly facilitate the introduction of wide screen pictures with their many advantages for improved pictorial effect, pleasing proportions, and increased number of full-length characters on the screen. In the latter case, the increase in size of the object imaged, an increase allowed by the altered proportions of the frame, still further increases the apparent sharpness of the picture. This effect can not be ignored, particularly in color photography, where there is a certain inherent lack of definition that this application of the anamorphoser will overcome, and without interfering with the technic of the color process.

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[1] MERTÉ, W.: "Construction Types of Photographic Objectives," *Handbuch der Wissenschaftlichen und Angewandten Photographie* (Vol. I, The Photographic Objective), Vienna (1932), p. 243.

[2] Abhand d. Koniglichen Gesellschaft d. Wissenschaften zu Gottingen. *Math. Phys. Klasse,* New Series, IV (1905), No. 3.

# PHOTOGRAPHIC EFFECTS OBTAINED WITH INFRA D NEGATIVE*

D. R. WHITE**

***Summary.***—*The characteristics of Infra D film, a stock designed specifically for specialized cinematography, possessing distinctive spectral sensitivity, are described. The sensitivity is limited to two regions at opposite ends of the spectrum, a relatively wide gap occurring between. Examples of the use of the film in producing special pictorial effects are given in the illustrations.*

Infra *D* film is a stock specially designed to meet the requirements of some of the specialized work of cinematographers. Its widest use is in the simulation of moonlight effects, but it has also been used for taking pictures through aerial haze.

The utility and special properties of this film are based fundamentally upon its distinctive spectral sensitivity. Fig. 1(a) shows that this sensitivity is effectively restricted to two regions at opposite ends of the visible spectrum with a relatively wide gap between. The film is, therefore, "green blind," so that it can not be used where true reproduction of visual brightness values is desired.

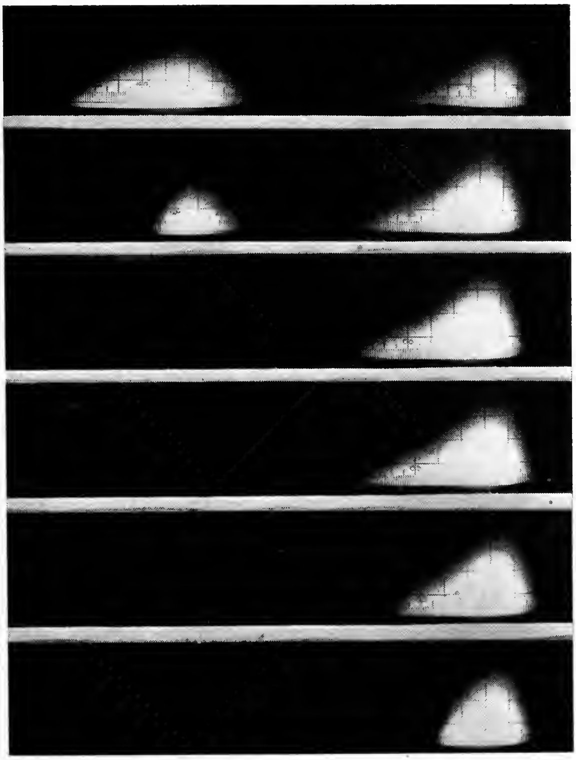
The sensitometric characteristics of Infra *D* are shown by the curves of Figs. 2 and 3. These curves resulted from rocked tray developments, in borax developer, of the film as exposed in a non-intermittent time scale sensitometer, in which the light source was an unscreened incandescent lamp operated at a color temperature of 2475°K. The crosses of Fig. 3 give time-gamma values for du Pont special panchromatic negative processed with the Infra *D*, and show that the two stocks are very similar in their development behavior. Thus, the Infra *D* introduces no new processing difficulties, and can be handled along with other negatives.

Further information concerning its sensitometric characteristics and its spectral sensitivity is contained in the group of curves of Fig. 4 and the spectrograms of Fig. 1. The spectrograms made through the filters were not all exposed for the same time, but the times were

* Received by the editor Oct. 24, 1932.

** Du Pont Film Mfg. Co., Parlin, N. J.

adjusted to agree partially with the increased exposure that would be required in practice and to emphasize pictorially the effective spectral regions. The sensitometer lamp was screened in turn by each of the series of filters used in making the spectrogram and, in addition, with the Wratten green or *B* filter. The spectrograms show the



(a)
(b)
(c)
(d)
(e)
(f)

FIG. 1. Spectrograms on Infra *D* film, exposed to incandescent light unscreened and screened by various Wratten filters: a, unscreened; b, $K_3$ filter; c, *A* filter; d, *F* filter; e, *70* filter; f, *88* filter.

nature of the light that was effective through each of the filters, and the curves show sensitometric characteristics of the film as exposed to that light. The relative placing of the curves along the log *E* axis is related to the filter factors for the various filters with that illumination, the displacement, in logarithmic units, of any curve from the white light curve being the logarithm of its filter

factor. The extreme displacement of the curve with the green or Wratten *B* filter emphasizes again the low green-sensitivity of the film. The gamma value obtained with the film depends upon the

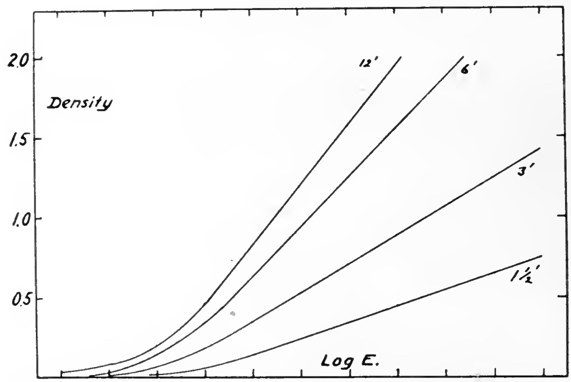



FIG. 2. H & D curves for different development times on Infra *D* film.

character of the light incident upon it, being greater for red than for white light.

The increased contrast resulting from red light exposure can be

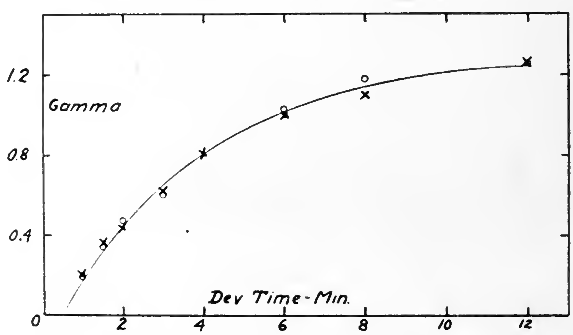



FIG. 3. Time gamma curve for Infra *D* film. Borax developer was used, rocked in a tray. The crosses show gamma values from du Pont special panchromatic negative developed at the same time.

put to very practical use in photographing through haze, when sufficient exposure can be given. The red filter aids in obtaining detail through the haze, the greater contrast also increasing its

visibility in the finished picture. Fig. 5 shows two pictures taken from an elevated point of land looking over miles of lowland on a day when haze was noticeably present. The rendering of detail in the picture taken through the red filter far surpasses that of the

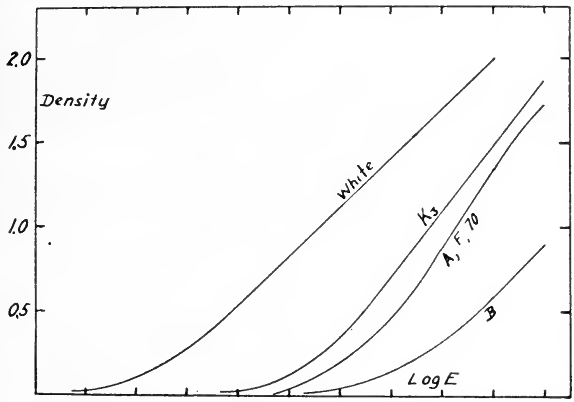



FIG. 4. H & D curves of Infra *D* film exposed to white light and to light screened by the various Wratten filters indicated.

picture taken with no filter; and, in fact, surpasses that of other test pictures made at the time using different filters and different types of film. The greater detail is due both to the penetration

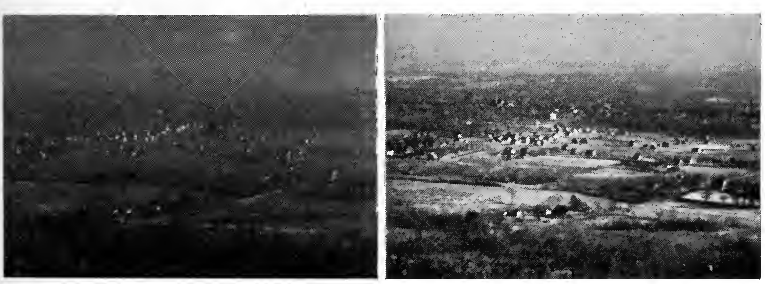


FIG. 5. Pictures taken from an elevated point of land: left, no filter on panchromatic film; right, *70* filter on Infra *D*.

of the red light through the hazy atmosphere and to the greater contrast of the film due to the fact that the latter was exposed to red light.

The photographs shown in Fig. 6 (a, b) and Fig. 7 are pictorial

in character, intended to typify some of the possibilities of the stock and to show the results to be expected from some of the filters frequently used with it.

FIG. 6(a).

FIG. 6(b).

FIG. 6. Pictures taken on Infra *D* film in bright sunlight on a July afternoon, printed on the same grade of paper: (a) no filter; (b) *F* filter. A $K_3$ filter produces an appearance intermediate between those of (a) and (b); *A*, *70* and *88* filters produce effects somewhat similar to those of (b) when the proper filter factors are used.

FIG. 7. Picture made from same negative as those of Fig. 6, but with different technic, particularly in the printing and selection of paper.

The filter factors, in bright sunlight, are given in the table below:

| Filter | Factor |
|---|---|
| $K_3$ | 16 |
| *A* | 64 |
| *F* | 64 |
| *70* | 64 |
| *88* | 90 |

These were used in obtaining the pictures shown, and are designed to give pictures of very similar overall density. The pictures, Fig. 6(a, b), were both printed on the same grade of paper, and show the relative changes produced by the filters. The pictures were taken on a bright July afternoon, but those taken with red filters, of which 6(b) is typical, resemble snow scenes as they are printed. Fig. 7 resulted from printing the negative used for Fig. 6(b) on a softer grade of paper; resulting, in this case, in quite a satisfactory night picture. It is sometimes desirable somewhat to underexpose such pictures in order to suppress shadow detail, or to underdevelop the negatives slightly so as to obtain the desired effect. The extent to which these methods are used depends upon the final effect desired. The dark sky and sharply defined shadows of night can be thus simulated in bright sunlight. Care must be used to have the rest of the atmosphere correct, of course, since windows and streetlights are often lighted at night but rarely in the daytime, and omission of these details might be fatal to the effect.

The limits of the use of this stock have by no means been reached. Trial and study by the users of the film will surely lead to unique and beautiful effects not touched on here.

# REMARKS ON THE MAKING OF SOUND RECORDS ON LENTICULAR COLOR FILMS

A. P. RICHARD*

***Summary.***—*Several precautions must be observed when variable density sound records are produced on 35-mm. lenticular film. An ammoniacal glycine solution is considered the most satisfactory developer. In order to secure the necessary individual control of the picture and sound records, it is suggested that the picture record be developed in a devoloper sufficiently charged with bromide, reversed, and then bleached, cleared, and dried. The sound record should then be exposed on the slightly sensitive emulsion remaining, and the entire film then developed, fixed, washed, and dried.*

*For better sound reproduction it is also suggested that the height of the embossed lines in the sound track area be less than that in the picture area.*

In considering the future of motion pictures in color, with the so-called lenticular films, it appears probable that their introduction into the industry will demand certain precautions. From an optical point of view it should be possible to avoid the reversal process, but at present it is necessary to use this method.

In the opinion of the writer, the application of the process to 35-mm. film would benefit by the use of Capstaff's methods with respect to the second exposure[1] since the reversal process using a solvent developer is a difficult one which requires control in the second exposure and development.

If a reversed image in colors be made in silver bromide, the gamma can easily be measured, and it appears that the development of the second exposure to gamma infinity does not always give the best colored image.

The loss of color in the reproduction, as compared with the original, can be put at approximately 15 per cent of the quality and the accuracy of the subject. Attention is called to the fact that an original on 35-mm. lenticular film has never, in the writer's experience, been made according to Capstaff's methods.** We may, therefore, infer

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** Since the preparation of this article, such films have been projected before the Society.

that in the majority of cases the original that was to be reproduced was not the best one that could be obtained.

A striking example can be found by considering the scales of blue and red colors. It is clear that the curve after the second development does not differentiate between a deep navy blue and black, and that the maximum density between black and blue varies within very narrow limits.

On the other hand, in reproduction, the "antidiffusing power" of the developer that is used for the first development must be taken into account. The "antidiffusing power" of a developer is a function of its reduction potential. The lower the reduction potential the less is the "diffusion," and the better is the definition. Hundreds of tests have shown that the ammoniacal glycine developer (Richard's formula) is one of the best for the lenticular process, since glycine has in this developer a very low potential, which approaches the desired value.

By photographing a white surface with lenticular film and using the reversal process, a film is produced in which the centers of the fields behind the lenticular elements are clear and the interspaces are black. If a silver salt be precipitated in the gelatin layer of this film, an emulsion of very fine grain with artificially darkened interspaces is produced. After the exposure of such a film in the camera it is possible to develop without reversal by means of an amidol developer and thus to produce a negative image in brilliant colors, demonstrating the role played by "diffusion."

The best developer is made according to the Lippman formula, which is used for interferential photography; but this formula can not be recommended owing to its tendency to form dichroic fog.

The preventing of moiré pattern in optical printing does not result in the same sharpness as is obtained in contact printing. It is necessary to accept a much lower degree of sharpness, which influences equally the rendition of the tricolor selection filter by each element. It is therefore obvious that it is very important to do everything possible to prevent "diffusion" from exerting a serious effect.

In making sound films by means of these processes, the above must be borne in mind because the sensitometry of reversed films with a solvent developer shows that industrial practice is attended by unexpected difficulties. These difficulties are, moreover, still more noticeable with solvent ammoniacal developers.

Very satisfactory definition can be attained by means of lithia and ferrocyanide combined with eikonogen and pyrocatechin *B*, but the colors are not as brilliant as they are when ammoniacal glycine is used, for instance. This developer without ammonia has certain advantages from the sensitometric point of view, but its "diffusing" action, although less than that of many others, is still too great to make it useful, especially when reproduction is concerned (Bonnerot & Richard, 1926).

To return to the sound film, it is well known that the printing

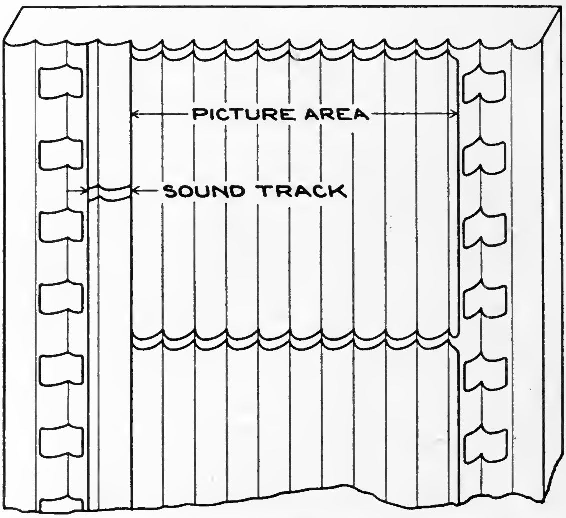


FIG. 1. Illustrating the embossings in the sound track area of the film. (Film 2× natural size; corrugations 90× natural size.)

necessitates certain precautions; the condition $\gamma_n \times \gamma_p = (K)$ should be satisfied completely.* As in the Western Electric movietone or the Tobis-Klangfilm processes, the average density varies between approximately 0.35 and 0.5.

If the sound be recorded on the margin set aside for the purpose, at the time of printing the picture, and the film be developed by reversal according to the known process, irregular results will be

* $\gamma_n$ = negative gamma; $\gamma_p$ = positive gamma; $K$ = constant.

obtained because nearly always one factor must be sacrificed for the benefit of the other.

While in this respect the variable width methods are much more flexible, the first development must be continued to such a point that after reversal the white spaces are perfectly clear; it being understood that the solvent reducing function has been perfectly balanced. These considerations lead to the conclusion that the sound printing is uncertain under these conditions and subject to all kinds of restrictions. The following method solves the problem.

The image is developed by the usual solvent reducing method, the developer being charged sufficiently with bromide. The image is reversed in permanganate; or better, in potassium dichromate, owing to its tanning action. The bleaching and clearing in sulfite at the beginning of the washing should take place in nonactinic yellow light. After this operation, the drying is carried out in a room illuminated with yellow light. The result is a positive in silver bromide where the margin has been set aside for the sound record. In printing, it should be remembered that the emulsion has lost its speed, owing to the destruction of the sensitivity centers of the emulsion grains.

The image is exposed again, giving it the necessary exposure for obtaining the best result. We then have a reëxposed positive picture image, a positive sound record in the latent image state, and a developer whose characteristics at an average temperature of 18°C. are known.

It is then easy to obtain a sound positive in colors of high quality by development in an ordinary developer, the only necessary precaution being to choose a developer that deposits reduced silver of a color as nearly neutral as possible. After fixing and washing, the final result is obtained.

By means of the process described, it is possible to calculate in advance the exposure time necessary for the sound and the picture in order that the sound may satisfy the sensitometric conditions that give the best results.

When a lenticular sound film is reproduced, it is noticed that the high frequencies are not rendered with great fidelity. The loss of audibility is not very great, but it is sufficient to be noticeable to a technician. Hence, the sound margin should be left smooth when the film is embossed (Pathé-Kodak patent). A different procedure can also be adopted by making a less pronounced embossing on the

margin, the direction of the lines being perpendicular to the slit* (Fig. 1).

The conditions for projection are identical to those of a film with a smooth margin, and no appreciable difference between the sound reproduced from a film with a smooth margin and the sound from film with a corrugated margin can be noticed by this method. Moreover, the advantage of the horizontal corrugation is retained for the picture, and additional frequencies are prevented from entering into the sound band that would otherwise increase the ground noise.

## REFERENCES

[1] U. S. Pat. 1,460,703, July 3, 1923; also U. S. Pat. 1,552,791, Sept. 8, 1925.

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* It should be noted that the embossings in Fig. 1 have been drawn on a greatly magnified scale compared with the film.

# MAKING A FADE-OUT BY AFTER TREATMENT*

C. E. IVES, L. E. MUEHLER, AND J. I. CRABTREE**

**Summary.**—*Fade-outs have been made for many years by moving the diaphragm or using a dissolving shutter in the camera during exposure. It is more convenient, however, to make a fade on either the developed positive or negative film by chemical means.*

*A modified Belitzski reducer formula of the "cutting" type is recommended for negative fade-outs. The film is introduced into a tube or tank filled with the solution with a positive acceleration so that the portion immersed last receives the least degree of reduction and a wedge effect is obtained. Another method consists in bleaching out the image in either a ferricyanide-bromide or a permanganate bleaching bath and redeveloping with the same manipulative treatment as for reduction. Positive fade-outs may be made conveniently by tinting with a black dye solution.*

*A mechanical device is described by means of which the necessary acceleration may be imparted to the film when immersing in the various solutions.*

The fade-out (and fade-in) has been used extensively to cause a pleasingly gradual transition between successive scenes in a motion picture, and is regarded in many cases as a necessity for the artistic presentation of the picture story. The fade-in and fade-out are essentially similar in nature although opposite in arrangement, so that for convenience only the fade-out is referred to in this paper.

The fade-out can be defined as a process whereby the picture is made to disappear from view by a diminution of brightness and contrast of the picture toward the end of a scene.

For many years fade-outs were made in the camera by decreasing continuously the light which reached the film through the optical system as the end of the scene was approached. Thus, as the fade-out progressed, the negative was more and more underexposed until at the end of the scene no image whatever was produced.

When a print is made from a negative which contains a fade-out the printing exposure is not varied within the scene, so that the frames included in the fade-out are progressively more dense and deficient

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* Communication No. 475 from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

in contrast. When such a fade-out is projected on the screen, the "fading" is seen to consist of the disappearance of, first, the shadow detail, second the medium tones, and finally the highlights.

As the art of editing developed, it became necessary to make the fade-out in the developed negative after the cutting process was completed. This necessitated either the insertion of a duplicate negative in which the fade-out was produced in the same manner as in the camera, or the alteration, by chemical treatment, of the original negative. In the latter case photographic reducing solutions were used to produce so-called "chemical fades."

Recently it has been considered desirable to insert fades in their proper places in the editorially cut print so that when it is viewed for final approval it is complete in all respects. Any cutting or alteration is done in the negative after this print has been approved. A method of making the required fades in the positive has been developed and will be described in this paper.

## THE NATURE OF A FADE-OUT

The first requisite of a good fade-out is that it shall cause the picture to disappear in a gradual and continuous manner. If it is abrupt, or has the appearance of being discontinuous, it does not serve the function for which it is intended. The fade-out must begin at a certain frame and go to completion between this point and the end of the scene. The average rate of change of density is determined by this length and the maximum density change which must be effected. The course of the change should be such that when the picture is viewed by projection the average brightness appears to diminish at a uniform rate.

If the change in brightness is to appear uniform, the density of each frame should be related to that of the next by an approximately constant difference. This is because, in general, the eye appreciates as equal steps of brightness those which are related to each other by equal logarithmic differences. Since density is a logarithmic quantity, equal density steps in the positive produce the desired logarithmic steps of image brightness on the screen. In order to produce these equal density steps in the positive the photographic reproduction characteristic requires equal density steps in the negative over a large part of the fade. A fade-out in which the density change follows this course has been found satisfactory.

**NEGATIVE FADE-OUTS**

In order to make chemical fade-outs in a negative which are similar in appearance to those produced in the camera, a photographic reducing solution must be employed which has the property of altering the densities of the negative in such a way that it will appear underexposed instead of underdeveloped. The so-called cutting reducers are of this type, and their action is illustrated by the curves in Fig. 1. In this figure, each curve represents the densities corresponding to a logarithmic series of exposures, as is usual for photographic characteristic curves. Curve *A* shows the densities before treatment with the reducer, and Curves *B*, *C*, and *D* the densities remaining after various degrees of reduction. As the

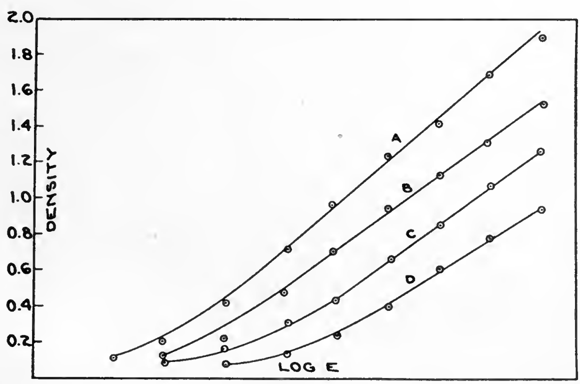


FIG. 1. Curves illustrating the action of cutting reducers.

time of treatment is increased, the lower densities are removed completely and all densities are lowered by an approximately equal amount which gives the desired appearance of underexposure. The data from which these curves were plotted were obtained by the use of a modified Belitzski reducer.[1]

In Fig. 2 are shown curves representing the change of density in a highlight which took place throughout the length of two camera fades selected at random from commercial productions. These curves show considerable differences, and the departure from a linear change in density is rather wide. The change in highlight density with increasing distance from the start of the fade-out is slow at first, and finally rises to an approximately constant rate. In view of the fact that a fade-out in which the highlight density changes at a

uniform rate throughout the fade has been found to have a pleasing and perfectly normal appearance, it can be concluded that the

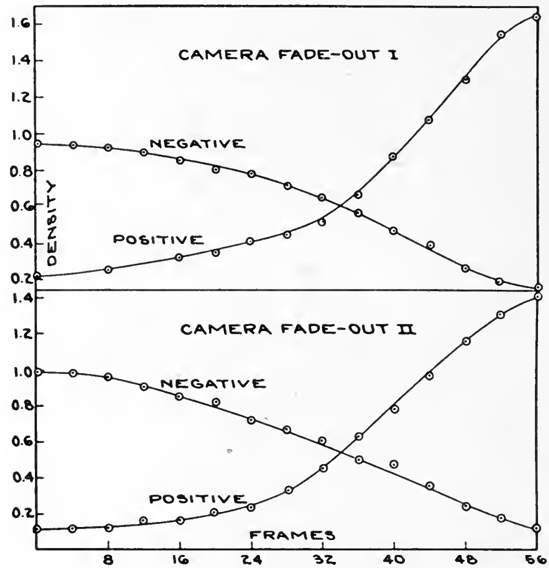


FIG. 2. Curves illustrating the change of density in a highlight occurring throughout the length of two camera fades selected at random from commercial productions.

particular shape of the curves in Fig. 2 indicate inefficiencies, and are merely the result of mechanical expediency.

### PHOTOGRAPHIC REDUCING SOLUTIONS FOR PRODUCING FADE-OUTS

In Fig. 3 the progress of density reduction with time of treatment using the modified Belitzski reducer is shown for a highlight area in a negative where the original density was 0.9. The formula for this reducer is given below.

*Modified Belitzski Reducer*
*(Formula R-8)*

| | |
|---|---|
| Ferric alum | 25.0 grams |
| Potassium citrate | 75.0 grams |
| Sodium sulfite (anhydrous) | 30.0 grams |
| Citric acid | 20.0 grams |
| Sodium thiosulfate (hypo) | 200.0 grams |
| Water to | 1.0 liter |

The Belitzski reducer, which is more stable, is recommended in preference to Farmer's reducer.

Farmer's reducer, as commonly used by photographers, consists of a 10 per cent solution of hypo in which is dissolved enough potassium ferricyanide to cause the reduction to proceed at the desired rate. Alternatively, a two-bath process is sometimes used which involves the use of a potassium ferricyanide solution of suitable strength for the first bath and an ordinary fixing bath for the second.[1]

The two-bath Farmer's reducer can be kept for long periods of time, but its use is more complicated and control is difficult. When the two-bath formula is used, the time of treatment in the first bath is varied to give increasing degrees of reduction from one end of the fade to the other. All parts of the fade are then given the same time of treatment in the second bath.

The three reducers mentioned above leave a faint stain image which is not ordinarily objectionable. When a cutting reducer is required which leaves no stain image, the iodine-cyanide reducer is satisfactory, but it has the disadvantage of being very poisonous. It consists of a solution of potassium cyanide to which a small quantity of iodine has been added.

Another method of producing a fade-out which is free from stain is to bleach the entire length of negative where the fade-out is to be made, and then to redevelop the image to varying degrees along the length to produce the densities required in the fade.

Either of the two bleach formulas given below is suitable for converting the silver image to one of silver chloride or bromide.

*Ferricyanide-Bromide Bleach*

(*Formula T-10a*)

| | |
|---|---|
| Potassium ferricyanide | 20.0 grams |
| Potassium bromide | 5.0 grams |
| Water to make | 1.0 liter |

*Permanganate Bleach*

(*Formula S-6*)

***Stock Solution A***

| | |
|---|---|
| Potassium permanganate | 5.3 grams |
| Water to | 1.0 liter |

***Stock Solution B***

| | |
|---|---|
| Sodium chloride | 75.0 grams |
| Sulfuric acid (concentrated) | 16.0 cc. |
| Water to | 1.0 liter |

For use, mix equal parts of *A* and *B* immediately before using. The mixed bath does not keep long.

The silver chloride image can then be redeveloped to the desired degree in a developer such as *D-16** diluted to one-fourth strength, after which the film is fixed in an ordinary fixing bath to remove the undeveloped silver halide.

Before redevelopment is attempted, the bleached image should be

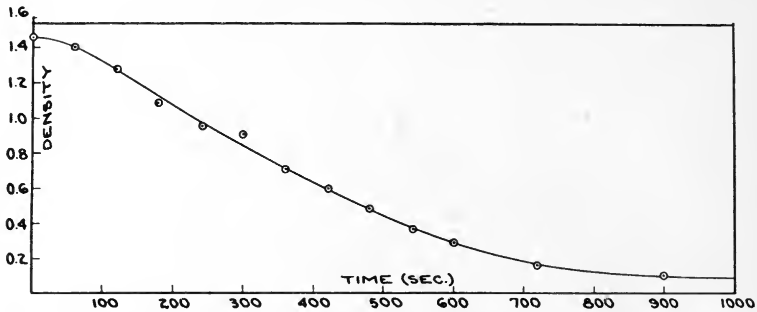


FIG. 3. Course of reduction of motion picture panchromatic type *2* negative film in modified Belitzski reducer.

exposed to strong daylight, but *not sunlight.* The result of the bleaching and redeveloping operation is equivalent to proportional reduction, so that the camera fade is not simulated so closely.

The curve in Fig. 3 shows that the diminution of the density of a highlight with the Belitzski formula is not strictly proportional to the time of treatment. The shape of this curve is such, however, as to suggest that if that portion of a negative where a fade-out is to be

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* *Motion Picture Film Developer*

(*Formula D-16*)

| | Avoirdupois | | Metric | |
|---|---|---|---|---|
| Water (about 125°F.) (52°C.) | 64 | ounces | 2.0 | liters |
| Elon | 18 | grains | 1.24 | grams |
| Sodium sulfite, desiccated (E. K. Co.) | 5 / 130 | ounces / grains | 158.4 | grams |
| Hydroquinone | 350 | grains | 24.0 | grams |
| Sodium carbonate, desiccated (E. K. Co.) | $2^1/_2$ | ounces | 74.8 | grams |
| Potassium bromide | 50 | grains | 3.44 | grams |
| Citric acid | 40 | grains | 2.72 | grams |
| Potassium metabisulfite | 88 | grains | 6.0 | grams |
| Cold water to make | 1 | gallon | 4.0 | liters |

made were led end first at a constant rate into the reducer, a very acceptable fade-out would be produced. This opinion is based upon the similarity of the curve produced in this way and shown in Fig. 4. Curve $A$ shows the densities remaining in the highlight of a negative treated in this manner, and Curve $B$ shows the highlight

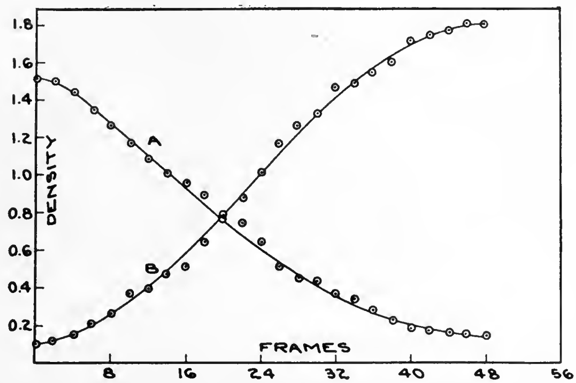


FIG. 4. Reduction of motion picture panchromatic type *2* negative film.

*A*, negative, time of treatment proportional to distance from end of fade-out.
*B*, print from *A*.

densities of a positive printed from it. A print including a fade-out made in this way was examined by projection and found very satisfactory and entirely typical.

Methods and apparatus for handling the film during a treatment of this kind are discussed later in this paper.

#### POSITIVE FADE-OUTS

It is assumed that a fade-out is to be introduced into an editorial positive print after it has been developed and when the editing is complete. A convenient method of darkening the film so as to simulate a fade-out is to stain the film with increasing quantities of a neutral black dye as the end of the scene is approached. A satisfactory method of controlling the density added in this way is to vary the time of bathing in an aqueous solution of a dye which has an affinity for gelatin.

No single dye having the desired properties was found, but a combination of three dyes in the formula given below produced a

visually neutral black with a projector low-intensity arc lamp. It would be possible to use these dyes in slightly modified proportion in case the spectral distribution of the light source used is somewhat different from that mentioned. The formula can be considered merely as a guide to the proper proportions, because various samples of the same dyestuff are often found to differ in purity.

*Visually Neutral Dye Bath*

| | |
|---|---|
| Acid anthracene brown B* | 8.7 grams |
| Toluidine blue** | 8.7 grams |
| Naphthol green** | 2.6 grams |
| Water to make | 1.0 liter |

In deciding upon the density to be added by dyeing, preliminary tests were made which showed that a maximum density of about 4.0 should be reached in order to obliterate the image entirely. This density seems rather high, but is necessitated by the fact that the contrast is not degraded by the addition of a uniform density over the picture. It is necessary, therefore, to increase the superimposed density to a point where even the brightest part of the image is covered effectively. This condition is usually attained when the added density is 4.0 because of several factors. Among these, the following are important:

(a) Visual contrast perception is greatly reduced at a screen brightness level equal to one ten-thousandth of the ordinary level.

(b) The adaptation level of the eye in an ordinary auditorium or theater is usually at a level which is much higher than that which would give the best contrast perception when the fade-out is in progress.

(c) The stray light falling on the screen is usually enough to obliterate the image beyond a brightness level reached during the fade.

From the considerations cited previously, it was concluded that a constant change in density with distance along the fade would be suitable. Tests of positive fades made in this way proved satisfactory on projection.

It was found that the density produced by the dye formula given above was proportional approximately to an exponential of the time of bathing, as shown by the curve in Fig. 5. In order to obtain,

* Grasselli Chemical Co., Inc., Empire State Bldg., New York, N. Y.

** Hoechst (marketed by General Dyestuffs Corp., 233 Fifth Avenue, New York, N. Y.).

on each frame, a density which is directly proportional to the distance from the end of the fade it was necessary to vary the time of treatment throughout the length of the fade in a manner which is functionally related to the exponential rate of growth of density with

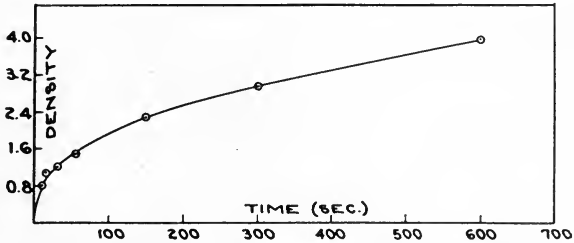


FIG. 5. Dye tinting of motion picture positive film.

time of treatment. A fade-out of this type, the curve of which is shown at *A* in Fig. 6, was made by timing the dye treatment according to the indications of the curve in Fig. 5, to give a constant rate of increase in density along the length.

Curve *B* in Fig. 6 shows the densities produced by leading the film at a constant rate into the dye solution, a procedure which, as might be expected, gives very poor results.

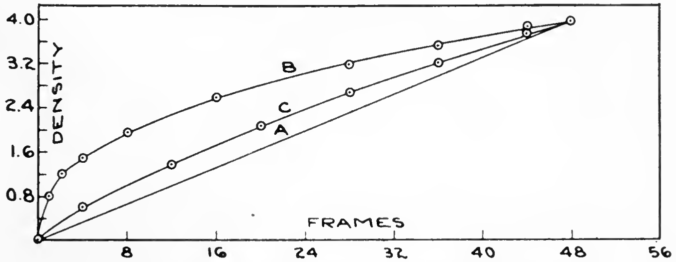


FIG. 6. Dye tinting of motion picture positive film.

*A*, added density proportional to distance of fade-out; *B*, time of treatment proportional to distance from end of fade-out; *C*, timing by simple crank and connecting rod mechanism.

Curve *C* in Fig. 6 shows the densities which resulted from times of treatment which could be given by a simple crank and connecting rod mechanism. This fade-out was found quite satisfactory.

Of the numerous ways of causing a varying degree of chemical

treatment from one end of the fade to the other, the simplest is to vary the time of treatment.

### DYE APPLICATION

In the case of the application of a dye solution to the film, the treatment can be carried out according to one of the methods for which instructions are given below.

(1) With the film strip lying emulsion side up on a flat surface, rub the surface lengthwise with a wad of cotton soaked with the dye solution. Start each stroke at the end which is to receive the lesser time of treatment. As each frame in succession receives its full time of treatment, blot it off and guard it from further contact with the cotton wad. As treatment is discontinued on one frame after another, the swabbing stroke is thereby shortened more and more. When the treatment of the whole strip is completed it should be free from spots of liquid and should not be washed but is ready for use when dried.

(2) If a large number of fades are to be made, it is preferable to treat several strips at a time by lowering them at a predetermined rate into a tank or tray containing the dye solution. That end of the strip which is to be bathed for the shortest time is immersed into the bath last. When the treatment is completed, draw the strips quickly from the bath, passing them through a squeegee to remove excess liquid from the surface. The fade is ready for use as soon as it is dry.

The equipment required for this operation depends upon the method of timing, and may vary from a wooden rod with hooks to which the various strips are attached, to a completely automatic machine by which the treatment is timed and the film withdrawn and squeegeed. The elaboration of the equipment will depend on the quantity of work to be done, but perfectly satisfactory results can be obtained with the simplest equipment. Methods of automatically controlling the time of treatment are discussed below.

### TREATMENT OF THE NEGATIVE

The mechanical handling of the negative during treatment is essentially similar to that of the positive, but certain limitations are imposed by the nature of the processes. Both reducing solutions and developers which are used in producing negative fade-outs act upon the image at a rate which is slower than the rate of diffusion from the solution into the gelatin. The consequence of this is that when the film is removed from the bath it contains a considerable quantity of unused solution which continues to work unless prevented by prompt action. The operation must be planned, therefore, in such a way that the treatment of all portions of the fade is completed simultaneously, and provision must be made for quick re-

moval to the next bath or the wash, as the case may be. Usually the action continues to a slight extent in the subsequent bathing or washing, but this can be minimized by adequate agitation of the film in the bath. At any rate, the further action can be made definite and uniform by proper handling, and allowance can be made for it in the determination of the time of treatment.

The following procedure assures a satisfactory fade-out when the times of treatment have been determined properly for the existing conditions:

(1) The Belitzski, one-bath Farmer, or Iodine-Cyanide reducing solution should be placed in a tank or tray large enough to accommodate the full length of the fade-out. Lead the strip into the bath at a rate which will give to each frame the time of treatment found necessary in previous trials. Allow the end which is to receive the least time of treatment to enter the bath last. Keep the liquid moving during use to assure uniformity of treatment. This is especially advisable in a shallow tray where natural circulation is very little.

When the treatment is complete, draw the strip out quickly, preferably through a squeegee, and place it in running water. Agitate thoroughly during the first minute of the wash to remove the reducer uniformly.

(2) When the two-bath Farmer reducer is used, the treatment in the first bath is carried out as described under method No. 1 above. When the film is removed from this solution, it is placed in the second bath where it should be agitated for 1 minute and then allowed to remain for about 10 minutes.

(3) The following directions apply for the bleach and redevelop process: Bathe the whole fade-out in the bleaching solution for a time somewhat longer than that required to show the pale yellowish white color through the film support. When bleaching is complete, remove the film and wash it. (If the permanganate bleach has been used, the dark brown stain should be removed, before washing, by a short treatment with a 1 per cent solution of sodium bisulfite.) When washing is complete, the fade-out is produced by lowering the film end first into an ordinary developing solution which may be diluted for convenience in timing.

The end of the fade-out which is to have the greatest density should enter the developer first. When all portions of the fade have received the proper times of development as determined in previous trials, the fade is removed quickly to an acid fixing bath, where it is agitated

for about 1 minute and then allowed to remain for 10 minutes. Fixation is followed by washing and drying, after which the fade-out is ready to be spliced to the negative.

It is advisable, before any of the above operations on negatives are undertaken, to harden the gelatin by treatment for five minutes in the following hardening solution.

*Hardening Solution*
*(Formula SH-2)*

| | |
|---|---|
| Formalin (40% solution) | 5.0 cc. |
| Sodium carbonate (anhydrous) | 5.0 grams |
| Water to | 1.0 liter |

If the negative has not been properly hardened, reticulation and frilling of the gelatin are liable to occur in the after processes.

### TIMING THE TREATMENT

Although it would appear that the motion of the treated strip of film should be stepwise so that all portions of a single frame receive the same treatment, this is not necessary. In a fade of the usual length, the change is so gradual that no variation in density from top to bottom of the frame can be detected if the fade is produced by leading the film into the treating solution by a continuous, instead of stepwise, motion. This makes possible a wider choice of methods of timing.

If the handling is to be entirely manual, then the stepwise method is probably the best choice, because of the difficulty of estimating the velocity in a continuous motion. It is recommended to adjust the concentration of the solution so that the process is complete in about 10 minutes.

If the time of treatment is to vary directly as the length of film traversed, the film can be led into the bath either one frame at a time at equal time intervals, or continuously by the use of any one of the common mechanical arrangements for producing motion at a constant rate. The use of mechanical timing means is very desirable, even though a large part of the process is to be carried on manually.

If the time of treatment is not required to increase directly as the length of film, then a more complicated timing means must be chosen. As shown in Fig. 5, for the dye treatment the relationship between time of treatment and length traversed is exponential, a relationship which is not attained precisely in a simple mechanical

device. If the motion is controlled by the use of a cam of special shape the apparatus is somewhat expensive and usually awkward and difficult to alter for varying the treatment.

A device described in a previous communication[2] may be used for the purpose because it can be adapted very easily to control the motion in any manner desired. This device is illustrated schematically in Fig. 7 with some of the other equipment which might be used for handling the film. The timing element proper consists of a tape moved at a constant rate under a set of small levers. Perforations

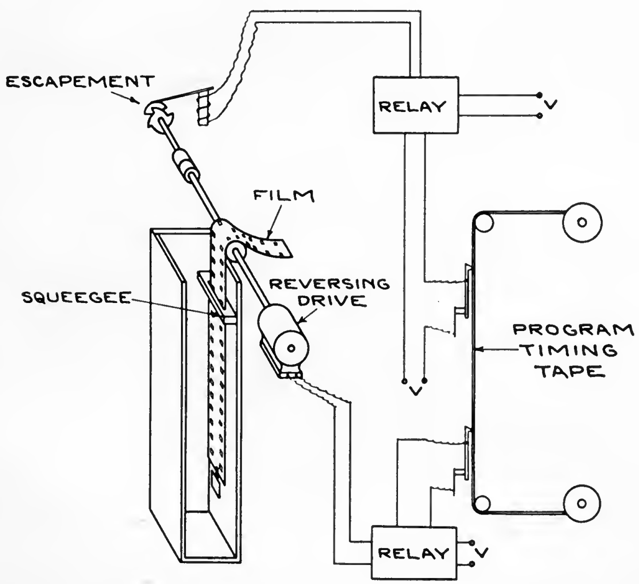


FIG. 7. Schematic drawing of machine for making fades with tape for program timing.

made in the tape at the necessary points move the levers, making electrical contacts by which the film advancement ratchet can be moved, motors started, stopped, reversed, *etc.*

There are other devices commercially available for timing a predetermined sequence of events, such as the blowing of time whistles, ringing bells, *etc.*, which might be adapted to this purpose. As mentioned above, there is always the possibility that an approximation of the motion required which is much more readily attained will be equally satisfactory in practice.

In the construction of apparatus for the treatments described in this paper it is necessary to take into account the corrosive nature of the solutions when deciding upon the material to be used in contact with the bath or the wet film.[3]

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[2] JONES, L. A.: "A New Non-Intermittent Sensitometer," *J. Frank. Inst.*, **189** (1920), No. 3, p. 303.

[3] CRABTREE, J. I., MATTHEWS, G. E., AND ROSS, J. F.: "Materials for the Construction of Motion Picture Processing Apparatus," *J. Soc. Mot. Pict. Eng.*, **XVI** (March, 1931), No. 3, p. 330.

# PRACTICAL PROBLEMS IN THE RECORDING AND REPRODUCTION OF MUSIC FOR MOTION PICTURES*

DAVID MENDOZA**

**Summary.**—*The paper opens with a few remarks on the relation between the musician and the engineer, and refers particularly to certain inadequacies in the recording and reproduction of music. The improper acoustical construction of sets and the inappropriate placing of artists and accompanists are alluded to. The difficulty of satisfactorily recording background music is briefly discussed, and a suggestion is made for overcoming the masking of dialog by background music. Further remarks are made on the size of sets and various points of technic in recording and duping.*

In discussing the practical problems that confront us in the everyday experiences on the stages of the studio, let us first disregard entirely the attitude of the industry as a whole—disheartening, to say the least—toward all endeavors of pioneering into new realms of imagination and fantasy. I believe that you will agree that unless startling improvements are made in the recording and reproducing of sound pictures, even beyond what has been done up to now, the industry may see a further divorcement between the theater and the audience than it has already seen.

The musician feels a common bond with the engineer, in respect to the reproduction of sound, first, because as an artist he depends so much upon the indulgence of the engineer and, second, because he is keenly aware of the well-nigh overwhelming technical problems. I have found the great majority of "mixers" I have worked with to be most genial and sympathetic; and have sometimes been amazed at the appreciation shown by these men, not only of sound as spoken of in decibels, but as regards a fine feeling for music in all its components of inspirational value—the balance of orchestration and the most illusive emotional factors that comprise an artistic performance.

Many present-day troubles result from two factors: (1) a lack of understanding of the other fellow's problem, and (2) the yet un-

* Presented at a meeting of the New York Section, Oct. 19, 1932.

** Warner Bros. Pictures, Inc., Brooklyn, N. Y.

conscious and unexpressed opinions of our audiences at large as to their reactions to "sound."

I feel that our stages are sorely lacking as to physical proportions and proper material for the effective recording of music. The stacking of deadening and in many instances reflective sets is most harmful. Our orchestras are shunted into all manner of positions and locations so as to be out of the way, as it were, of camera lines, and to be "conveniently" placed. Soloists are usually placed at absurd distances from the accompanists. Under such conditions, balancing for the mixer becomes merely a catch-as-catch-can affair. Even on the coast, with the stupendous stages found on all the lots, the sets are generally built with a thought only for the cameras.

Another factor that results from a lack of coöperation and understanding between departments refers to the matter of orchestration. The mixer generally hears the first performance of the musical compositions in his monitor room, and is not generally aware of some of the niceties of the orchestration, which should be determined by the playback.

A few weeks ago we had occasion to place the orchestra on a platform about four feet high, which happened to be built for use as a bridge in a scene to be shot the next day. By placing the orchestra on this platform, with its good air space beneath and all the "life" resulting from the platform, we were afforded one of the most satisfactory recordings obtained in a long time. This is a point upon which I put a great deal of stress, for orchestras are expensive and unless we obtain satisfactory results the efforts and expenditure involved will have been greatly vitiated.

Now we come to one of the most deplorable facts in connection with music in motion pictures, namely, "background" music. Of course, where a picture is silent as far as dialog is concerned, the music has a pretty good chance to come through satisfactorily, but when the characters on the screen speak, the music is wholly ineffective and in any case unsatisfactory. If we were to have an orchestra in the theater to supply mood and background music for pictures, the music should emanate from a source entirely different from that from which the dialog would come. It would be easy to "balance" the music and dialog, and lose none of the effectiveness of either one or the other. Would it not be possible to develop a double sound track, one on each side of the film, and place the projecting horns at different places in the proscenium of the theater? One track could

carry the music and the other the dialog; the two tracks could be reproduced on different systems and each could be operated independently of the other and reproduced from different points of the proscenium. This thought may be very impracticable, but as I should like very much to see something done in this connection, as I feel sure that the proper musical accompaniment of pictures would greatly assist in improving the reaction of the audience. I believe that you will all agree with me that up to the present a really effective background musical score has not been accomplished.

Also, when a dramatic scene is on the screen and silence prevails for a few minutes, the issuance of music from the same source whence comes the dialog seems unnatural. The producers always try to create an *apologia* for the music, and either place a radio or a phonograph in the scene. The audiences are becoming aware of this clumsy form of excuse, and are making many humorous comments about it.

I mentioned before my sentiments regarding the size of our stages. In the case of close-up recordings of solo instruments, they do not apply; but when an orchestra of symphonic proportions is employed we have found it well-nigh impossible to allow the men to play in full tone *fortissimo*, as they would in a concert hall. On the radio we hear reproductions of symphony orchestras with a great deal of satisfaction as regards results. Why can we not achieve as good results on our screen? The only remedy that I can think of is to utilize recording space so that it permits placing the microphones at a distance that would allow a natural performance and yet provide good acoustical results when reproduced. The new developments recently made in extending the range of reproduced frequencies could then be fully appreciated.

You have no idea of how great is the difference in the feelings of musicians when they are allowed to play on a stage that is "alive" and spacious. Everything seems to be pleasant and simple. The effect is purely psychological, but it is one of the main factors in our particular work. The conditions of recording have a tremendous effect upon the performer. So far, men like Respighi and Ravel have not been enticed into the motion picture field, and I think that this is mainly because the conditions existing in recording studios are in no way as conducive as they should be to a high standard of artistic achievement.

I remember a story that was told to me about Fritz Kreisler. The

occasion was a recording date for the Victor Company. Kreisler took out his violin, stepped before the horn (this was in the "good" old recording days), and noticed that he was standing on a rug. He asked the reason for the rug and was informed that it was necessary for acoustical reasons. Thereupon Mr. Kreisler expressed himself as being unable to play unless he stood on the bare floor. This story may sound far-fetched and may be foolish as far as net results are concerned, but as the performer was Mr. Kreisler and none else, the rug was removed.

Now imagine our trying to perform on crowded stages filled with all sorts of deadening materials, such as flats, that set up all kinds of reverberations, and situated so that we have no idea of what the net balance will be. Yet we struggle on in the hope that some day our work will be facilitated to a point that will spur our enthusiasm and imagination.

I do not believe that any method of equalization for duping purposes is advisable, as I have found that if the original sound track does not possess all the qualities desired, any attempt to equalize for the purpose of building up highs or lows generally introduces some kind of distortion.

I am aware that there are various new improvements being utilized and experimented on that I understand give results far superior to what we are producing at present. I sincerely hope that the producers will be made to realize the advisability of adopting these improvements. The engineers must sell these ideas to these producers, especially in the matter of theater equipment; for, as is well known, many of our efforts are vitiated in the net results heard in the neighborhood theaters and, in many cases, I am sorry to say, in the so-called de luxe motion picture houses.

Of course, few theaters have been built particularly for exhibiting sound pictures. We hear our product in our small projection rooms, and are very often enthusiastic over the results. Later we hear it in one of the Broadway theaters, and the difference is unbelievably disappointing. The music sounds thin, without the body of sound that I know was contained in the original recording. High tones are lost, low tones are lost—"fuzz," "edge," sprocket hole modulation are produced. The problems in this connection are too numerous to relate and I am in absolute sympathy with the engineers' efforts. But when I hear my oboe, clarinet, violin, or trumpet sound like a Chinese cat, I resent it! I must resent it! Poor balance can be

corrected even in mixing, poor performance in rehearsal—and "fuzz" and "edge" must be eliminated.

A word for duping. This is one of the phases of our business that I think is still in its most elementary state. An evil in itself and unavoidable from a practical and economic point of view—but the relation between the dynamics of music back of dialog plus effects is a matter of showmanship in its most elementary phase. The dupers and mixers are endeavoring to be showmen in this sense, and in many instances they are. The mere audibility of any sound, either music or effect, is not enough. That the importance of the sound lies in the frame of the drama or the comedy is the factor to bear in mind. A moment of drama must be recognized as such, and soft and subtle treatment is necessary.

Now I do not believe that all these shortcomings are due to inadequate equipment. I attribute a great deal of it to faulty and inadequate acoustics. From the standpoint of dialog, the motion picture is well exhibited; but from the standpoint of sound, I am sorry to reiterate that most of the comments of those who pay attention to this part of the entertainment are always most disappointing.

In conclusion, I wish to state that complete coöperation and very close association must exist between the music department and the recording department. A complete understanding of each other's problems and the exchange of ideas and an honest criticism of each other's work must be the rule. Temperament will always be present, but if honesty exist fundamentally, good results will follow.

**ERRATUM**

The following correction should be made in the paper, *Standards and Requirements of Projection for Visual Education*, by Chauncey L. Greene, beginning on page 424 of the November, 1932, issue of the JOURNAL:

On page 432, sixth line from the bottom, the phrase "this class of screen" should read "the translucent type of screen."

## NEW APPARATUS

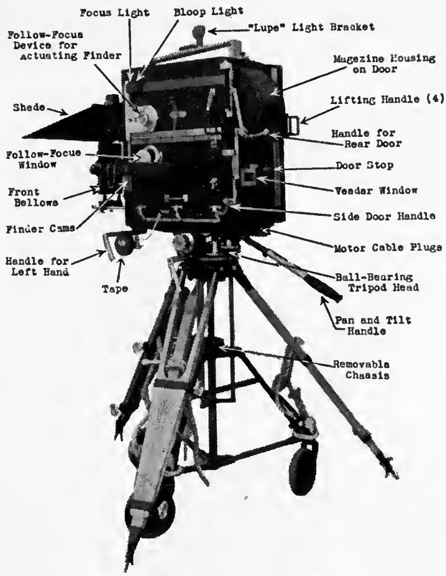
*At recent meetings of the photographic section of the Technicians Branch of the Academy of Motion Picture Arts and Sciences, and of the Chicago Section of the S. M. P. E., several pieces of new equipment were exhibited and discussed. The description of a few of the devices follows. Illustrations were supplied by Mr. J. G. Frayne, Chairman of the S. M. P. E. Progress Committee and Mr. C. E. Phillimore of the S. M. P. E. Chicago Section.*

*Bell & Howell Rotambulator* (Fig. 1).—With this new type of support, the camera may be moved vertically from a point 2 feet above the floor to nearly 8 feet. Present models utilize a worm drive for this movement but future models may be equipped with a hydraulic

*Courtesy of Bell & Howell Co.*

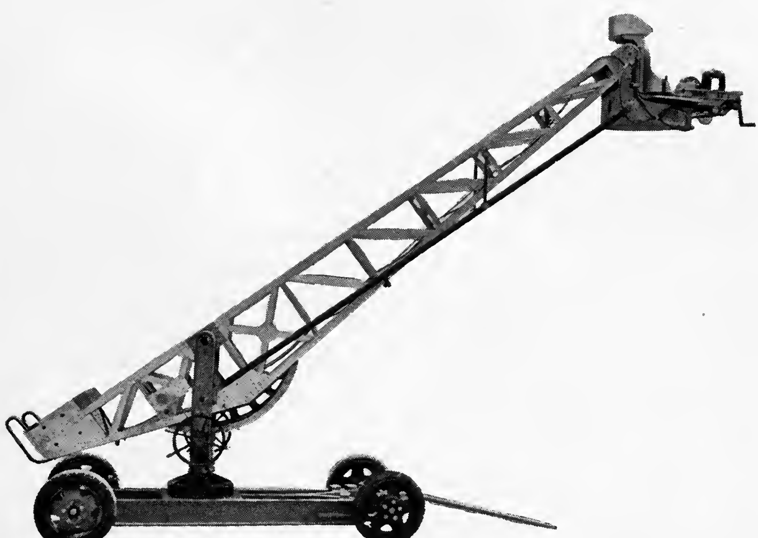
FIG. 1. Rotambulator.

hoist. The usual pan and tilt, and horizontal movements are available. The panoramic movement is effected by hydraulic means, and is controlled by pedals operated by the cameraman, who sits on a seat arranged to revolve with the camera. The device is




*Courtesy of Paramount Publix Corp.*

FIG. 2. Sound blimp.

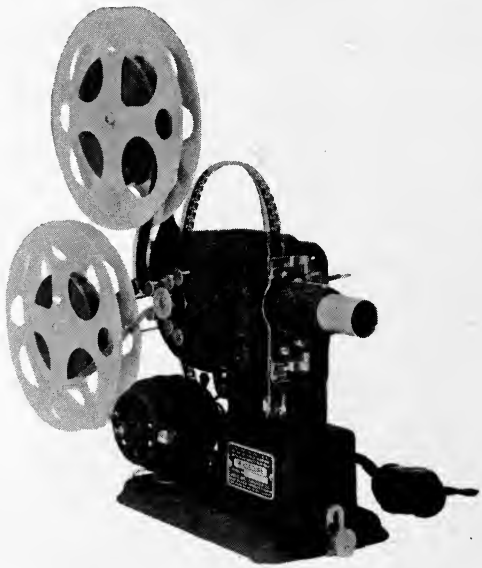


*Courtesy of Paramount Publix Corp.*

FIG. 3. Camera crane

mounted on a heavy frame equipped with three small wide wheels having rubber tires. A hand bar is provided for moving the rotambulator and the cinematographer.

*Paramount Sound Blimp* (Fig. 2).—The illustration is self-explanatory. Note that the camera and tripod may be lifted quickly and easily by the rolling tripod for moving from one setting to another.



*Courtesy of Peko, Inc.*

FIG. 4. Projector.

*Paramount Camera Crane* (Fig. 3).—This crane is so designed that it may be passed through a 24-inch doorway. It is much more flexible and lighter in weight than many of the earlier cranes used for motion picture camera work.

*Peko Projector* (Figs. 4 and 5).—The frame consists of a white-brass casting about which the entire mechanism is constructed. The gear train comprises four spur gears and two metal gears. All bearings are lubricated from tubes leading to the top of the machine. The intermittent movement consists of a conventional cam and a double claw straddling the perforations. A two-blade 90-degree shutter is employed, the picture being projected at the rate of 20 frames per second. The reflector is made of chromium-plated brass.

The base of the projector houses a transformer or, in the case of d-c. supply, a resistor. The projectors are designed to be operated by alternating or direct current. The driving belt is crossed to permit reversing the machine or rewinding the film.

The film passes through the projector without being twisted and ball bearings are used throughout. The reels will accommodate 400 feet of film.

One model is provided with a rheostatic speed control and a special switch by means of which a resistor is introduced into the lamp circuit when the motor is at rest, thereby reducing the illumination and heat sufficiently to permit showing still pictures. Forced ventilation is also provided.

*Courtesy of Peko, Inc.*

FIG. 5. Projector mounted in carrying case; *right,* for direct projection through front of case; *left,* for industrial use with daylight screen.

## BOOK REVIEW

**Einfuehrung in die Tonphotographie. (Introduction to Sound-Photography.)** John Eggert and Richard Schmidt. *S. Hirzel*, Leipzig, 1932, 137 pp.

This introduction gives a thorough résumé of methods of recording sound photographically. After briefly describing the elementary physics of sound recording, it deals with the various electroöptical phenomena and their application to modern methods of recording sound.

The greater portion of the book is devoted to the fundamental principles of photographic recording. In some ways very elementary, these chapters furnish a rather complete analysis of most of the known photographic effects on the sound record and discuss the influence of these effects on the final results: the reproduced sound. Following a treatise on sensitometry is a chapter on the fundamental requirements for recording and reproducing sound without distortion. Both the variable area and the variable density systems of recording are discussed, as well as the noiseless recording systems.

The latter part of the book presents results obtained with Agfa Film *TF3* and *TF4;* films especially made and adapted for recording sound, which are extensively used in Europe. A proposal for standardization and citations of German, English, and American literature conclude the volume.

Many graphical charts and drawings, which can be easily understood with but little knowledge of mathematics, illustrate the formulas.

This book should be of great value to all those interested in the problems of recording sound.

W. Schmidt

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## SOCIETY ANNOUNCEMENTS

### SPRING, 1933, CONVENTION

**April 24–28, inclusive; New York, N. Y.**

At the meeting of the Board of Governors held on October 5 at New York, plans for the Spring, 1933, Convention were initiated: the meeting is to be held at New York, N. Y., and of five days duration—April 24 to 28, inclusive.

Mr. W. C. Kunzmann, chairman of the Convention Committee, assisted by Mr. H. Griffin, chairman of the Local Arrangements Committee, is proceeding with arrangements to hold the Convention at the Hotel Pennsylvania, in the *Salon Moderne.*

Mr. O. M. Glunt, chairman of the Papers Committee, promises an extremely interesting schedule of papers; the number of papers to be presented will be limited to what can be accommodated in the allotted time without haste or crowding, a feature that will assist considerably in the selection of papers from the point of view of technical quality, with less emphasis on quantity.

An exhibit of newly developed motion picture equipment will be held, as at past Conventions, which should prove of considerable interest to every one interested in motion picture engineering. Manufacturers of equipment are invited to communicate with the General Office of the Society, 33 W. 42nd St., New York, N. Y., for information regarding the regulations of the exhibit and arrangements for space.

Plans are being made to assist out-of-town visitors to the Convention to pass an interesting time while in New York, and special film programs and trips of interest will be arranged for. Full details of the program, including hotel rates and other pertinent information will be mailed to the members of the Society at a later date. Members and friends of the Society are urged to make every effort to attend the Convention.

### PACIFIC COAST SECTION

At a meeting of the Section held on December 14 at the Walt Disney Studios in Hollywood, several descriptions of the technical processes involved in producing animated cartoons were presented. Chairman E. Huse announces an interesting series of meetings for the coming season, and all members of the Section are urged to attend the meetings regularly and contribute to the activities of the Section; all meetings will be open to both members and friends.

### COMMITTEE ON THE CARE AND DEVELOPMENT OF FILM

Reports of the work of the two sub-committees of the Committee on the Care and Development of Film, one dealing with exchange practices and the other with laboratory practices, have practically been completed and will be published

in the JOURNAL in the next month or so. This work represents a new activity of the Society, begun hardly a year ago, in collecting all the important data on current practices in the handling of film in the exchanges and in the laboratories. Much yet remains to be done, of course, particularly in the matter of paving the way toward standardization of technic; the work of this year, however, was directed more toward determining the nature of present technic and correlating and reconciling divergent technics.

## COMMITTEE ON STANDARDS AND NOMENCLATURE

In the November issue of the JOURNAL the report of the Committee on Standards and Nomenclature, which was presented before the Society at the Washington Convention last October and returned to the Committee for further consideration, was published. Accompanying the report was an invitation to all readers of the Journal who might be interested in motion picture standardization to submit in writing to the General Office of the Society, comments on or criticisms of the report. Action of the Board of Governors of the Society will be taken at their next meeting, on January 20 at Rochester, N. Y., toward the validation or rejection of the proposed standards in the light of the comments received. Those who desire to comment on the report are urged to do so immediately, so that their communications may be received in time for the consideration of the Board.

## SUSTAINING MEMBERS

Bausch & Lomb Optical Co.
Burnett-Timken Laboratories
Eastman Kodak Co.
Electrical Research Products, Inc.
RCA Victor Co., Inc.

## HONOR ROLL
### OF THE
## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

### PAMPHLETS, BOOKLETS, AND CATALOGUES

Manufacturers of motion picture equipment and supplies are requested to send to the General Office of the Society copies of their descriptive pamphlets, booklets, and catalogues as issued. Notices of the issuance of this material will be published in the JOURNAL, advising the readers that the material may be obtained free of charge by addressing the manufacturers named. This editorial service has been established in order to acquaint readers of the JOURNAL with the commercial developments of the motion picture industry as quickly as they occur.

# JOURNAL

OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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*CONTENTS*

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## OF THE SOCIETY OF
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SYLVAN HARRIS, EDITOR



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# THE PHOTRONIC PHOTOGRAPHIC EXPOSURE METER*

W. N. GOODWIN, JR.**

**Summary.**—*This paper describes a new photographic exposure meter, which measures the brightness of the scene to be photographed. It utilizes for its light measuring element two Weston photronic photoelectric cells connected in parallel to, and mounted in the same case with, a permanent magnet movable coil indicating instrument calibrated in units of brightness: candles per sq. ft. The cells are of the direct action dry disk type, which transform light energy directly into electrical energy, requiring no battery, and having an unlimited life. They are mounted in tubular depressions to limit the area of the scene covered.*

*A simple mechanical dial calculator attached to the meter case translates light values into exposure values by a single setting of a dial, after having set the calculator once for all for the speed of the film being used. The calculator has the novel feature of providing means for fitting the brightness range of a scene as determined by its darkest and brightest objects, to the correct film range indicated on the dial as lying between the darkest and brightest objects which the film will correctly expose, for the indicated shutter speed and aperture.*

There is probably no problem encountered by the photographer that is more troublesome than that of determining the correct exposure. Even after long experience one is usually in doubt in estimating exposure, especially at times other than mid-day and for any but the most usual subjects. For such conditions, estimates made visually are little more than guesswork. The very fact that the human eye is capable of adapting itself automatically to such extreme variations in light intensities makes it exceedingly inaccurate as a means for judging the relatively narrow range of light values for correct exposure, especially under unusual conditions.

Light tables, which give average values arranged according to months, time of day, and character of lighting, are in extensive use; but they fail during early morning and late afternoon, and under unusual and abnormal conditions. While it is a fact that modern films have a wide latitude, or *film range*, as it is termed in this paper, the actual scene exposure range, or choice of exposure, is very narrow,

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* Received by the editor, September 28, 1932.

** Weston Electrical Instrument Corp., Newark, N. J.

as will be referred to later in detail. It is for this reason that among the many exposures one makes, only a few are really satisfactory, as every photographer knows.

To obtain correct exposure, therefore, it is necessary to be able to measure the actual light intensities at the time the exposure is to be made.

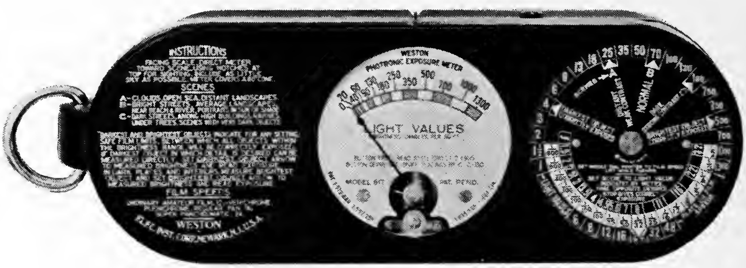


FIG. 1. Front view of meter.

The exposure meter described in this paper utilized for its light measuring element two Weston photronic photoelectric cells. These are of the direct action, dry disk type, in which the light energy is transformed directly into electrical energy, requiring no battery for their operation. As they are purely electronic in their action, their lives are unlimited as far as is known.

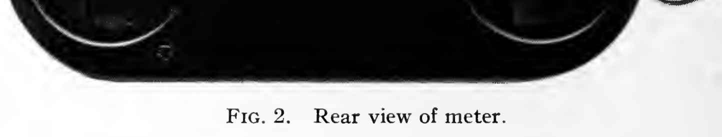

FIG. 2. Rear view of meter.

The cells are directly connected to an electrical measuring instrument mounted in a common case as illustrated in Fig. 1 showing a front view, and in Fig. 2 showing the cell construction in the rear. A mechanical calculator is provided for translating the instrument indications into exposure values.

The instrument is calibrated to read in terms of the brightness of the subject to be photographed, as this is the quantity that determines the intensity of the illumination falling upon the plate to be exposed.

Before discussing the exposure meter in detail it is desirable to consider briefly some of the fundamental relations of illumination and exposure. To show the relation between the brightness of the subject and the resulting illumination on the plate or film in a camera, refer to Fig. 3.

Let $A$ be a portion of the subject to be photographed, which is either self-luminous or becomes luminous as a result of reflection of light from the sun, sky, or other illuminant. Assume that it has a uniform brightness of $B$ candles per sq. ft. and that it is situated in a plane perpendicular to the axis of the lens, at a distance, $D$, from the lens, relative to which, the distance between lens and aperture may be neglected. For simplicity of illustration, assume a single lens and a diaphragm with a circular opening having a diameter, $d$. Then the image of the surface $A$, properly focused on the plate, will have an area $a$ at a distance, $F$, from the lens, all distances being measured in the same unit. Each point, $p_1$, of the object will produce a cone of light rays having as a base the circular opening of the diaphragm as shown by the solid lines, which again reunite in a corresponding point, $p_2$, of the image.

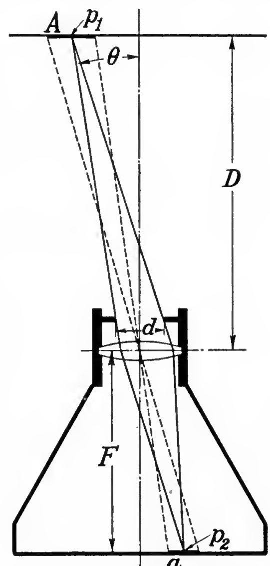

FIG. 3. Light diagram and illumination in a camera.

The total luminous intensity of the surface $A$ is the product of the area by the brightness, or $AB$ candles, and the intensity in the direction of the lens is $AB \cos \theta$ candles. The resulting illumination at, and in the plane of the diaphragm, is

$$\frac{AB \cos^4 \theta}{D^2}$$

foot-candles in accordance with the well-known laws of light, where $(D/\text{Cos } \theta)$ is the distance of the object from the lens, remembering

that the light enters $d$ at an angle $\theta$ with the normal and assuming that all distances are measured in feet.

The amount of light, in lumens from the surface $A$ entering the diaphragm, is the product of the illumination at that point by the area of the opening, or

$$\frac{AB\cos^4\theta}{D^2} \times \frac{\pi d^2}{4}$$

Part of this light is absorbed by, or reflected from, the lens, and only a part is available for the image, which is obtained by multiplying the total light by the transmission factor of the lens, $T$; or the light available for the image is

$$\frac{AB\cos^4\theta}{D^2} \times \frac{\pi d^2}{4} \times T \text{ lumens}$$

Now this light is distributed over the image having an area $a$ so that the illumination at $a$ is the total light in lumens divided by the area, or

$$E = \frac{AB\cos^4\theta}{D^2 a} \times \frac{\pi d^2}{4} \times T \text{ foot-candles}$$

From well-known optical laws the following proportionality holds,

$$\frac{A}{a} = \frac{D^2}{F^2}$$

Substituting for $A/a$ in the above equation for $E$, its equivalent $D^2/F^2$ and rearranging terms, we have

$$E = \frac{B}{(F/d)^2} \times \frac{\pi}{4}\cos^4\theta \text{ foot-candles}$$

which shows that the illumination on the plate available for producing an image is proportional to the brightness of the object, independent of its distance from the lens except for its slight effect upon the distance $F$, which will be referred to later, and inversely proportional to the square of the ratio of the focal length of the lens to the diameter of the diaphragm opening. It also shows that the illumination is not uniform over the area of the plate but, under the assumed conditions, falls off from the center in proportion to the fourth power of the cosine of the angle of incidence of the light.

Practically all lenses are marked by their manufacturers with $f$/numbers or some function of them, which are the ratios of the principal focal length of the lens to the diaphragm openings. Call

this value $f$, and substitute it for $(F/d)$ in the equation; insert the numerical constants, and change to meter-candles, which is the unit usually employed in photographic work, by multiplying by 10.76; we obtain

$$E = 8.45 \frac{BT}{f^2} \cos^4 \theta \text{ meter-candles}$$

Assuming an average angle $\theta$ of 16 degrees and a transmission factor for the lens of 76 per cent, the measured value for a well-known make of lens, which, however, may vary considerably for different makes of lenses, we obtain the illumination of the image:

$$E = 5.4 \frac{B}{f^2} \text{ meter-candles}$$

### ELEMENTARY THEORY OF EXPOSURE

When light falls upon a photographic plate or film, the action upon the sensitized material depends upon the intensity of the illumination and upon the time the light is allowed to act. Expressed mathematically, the exposure is $e = Et$, where $t$ is the time the illumination $E$ acts upon the film in seconds.

Then substituting the value for $E$ deduced above, we have

$$e = Et = 5.4 \frac{Bt}{f^2} \text{ meter-candle seconds}$$

It is thus shown that the brightness of an object is the true criterion of exposure, and not the intensity or quality of light falling upon the object, as is frequently used. The equation further shows that the exposure is inversely proportional to the square of the $f$ number, as is well known.

For objects at relatively great distances from the lens, the $f$ in the equation depends upon the principal focal length of the lens, and for convenience the maker of the camera bases the $f$/numbers upon this value. These $f$/numbers are sufficiently close to the actual values for distances within 10 times the focal length of the lens. The actual $f$/number for any distance can be computed by the following equation derived from the usual lens equation:

$$f_1 = \left(\frac{n}{n-1}\right) f,$$

where $f_1$ = actual $f$/number, $f$ the marked number, and $n$ the ratio of the distance from the object to the lens, to the focal length of the lens.

We have considered so far only the illumination available on the photographic plate and the time it acts, the product of which is the exposure, and we shall now discuss briefly the action of this exposure upon the photographic emulsion so as to determine the direct relation between the brightness of an object to be photographed and the resulting effect in the final negative.

When light falls upon a sensitized plate or film, a physical change takes place that is well known, the resulting change depending upon the intensity and color of the illumination on the plate or film; upon the time it acts; and upon the sensitivity of the emulsion. When the plate is subsequently developed, the sensitized silver salts that were acted upon by light are reduced to metallic silver,

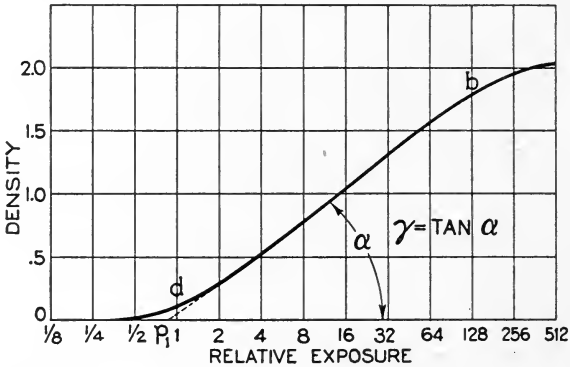


FIG. 4. Typical H & D characteristic curve of photographic plates and films.

and the amount of reduction is a function of the exposure and the time of development. This effect was made the subject of scientific investigation by Hurter and Driffield. They found that, for a given development, if values of density be plotted against the logarithms of the exposures, a characteristic curve results, as shown in the typical curve in Fig. 4, known as the H & D curve. In the straight portion the relative densities are proportional to the logarithms of the exposures, as is required for correct rendering of light values. Hurter and Driffield further found that the actual densities increase with the time of development. The density $D$ is defined as the logarithm, to the base 10, of the opacity of the film, which is the ratio of the light incident upon the film to that which passes through it.

For purposes of illustration the abscissas are designated in terms of relative exposure, and are plotted logarithmically, each value being double that of the preceding one. Hurter and Driffield found by experiment that the slope of the curve increases with the time of development and that the straight portion, when extended, swings around a point $p$ which, for simplicity, is shown as lying in the line of zero density, but which frequently lies below it. The tangent of the angle that the straight portion makes with the horizontal is known as $\gamma$ (gamma). The value of $\gamma$ is a measure of the contrast of the film; that is, it gives the rate of change in density with respect to changes in the logarithm of the exposure.

The exposure corresponding to the point at which the straight portion intersects the horizontal axis is known as the inertia, and its reciprocal is customarily used as a measure of the speed of the film. On the curve of Fig. 4 the inertia is the exposure corresponding to the point $p$; but where $p$ lies below the line, the inertia value moves along the exposure axis with changes in $\gamma$, showing that the emulsion speed varies with development time.

The curve may be divided into three parts: (1) the lower end, which deviates from a straight line at the point $d$, known as the toe. This is the region of underexposure. (2) The straight portion, which is the region of correct exposure. (3) The upper portion, which extends beyond the straight line at the point $b$ known as the shoulder, is the region of overexposure. These terms do not mean, however, that the under and overexposure regions are not frequently useful and often used. Darkest subjects and the brightest highlights of any scene may well extend into the lower and upper regions, respectively.

The curve illustrated is typical of average commercial films. It will be noted that the range of the film where correct exposure may be obtained represents an exposure ratio of about 128 to 1. This ratio varies for different types of film and with the time of development, but for the purposes of exposure meter design, this safe average value for the film range was used.

Any given scene to be photographed consists in general of objects of differing degrees of brightness and color, and the problem in exposure is to adjust properly the range of light values of the scene so that it lies within the range of the straight-line portion of the characteristic curve. For example, if in a given scene the ratio of the brightness of the brightest object to that of the darkest object

in which detail is desired is 32, say, then the brightness range will be only one-fourth the film range, that is, 32 divided by 128; and the scene range of 32 will be correctly exposed if it is placed anywhere on the 128 to 1 film range. On the other hand, if the brightness range is approximately 128 to 1 then the photographer has no choice and the exact exposure must be known.

As briefly referred to earlier in the paper, modern films have great latitude or film range, but it does not follow that they have an equally great scene exposure range, that is, choice of exposure. In the example given above for the relatively narrow brightness range of 32 to 1, if this range is placed at the low end of the film range, then any exposure less than the correct value will result in underexposure of the lower tones, but an increase in exposure of 4 to 1 will still give a good negative. If the scene range is set to give a medium density in the film range, then an error in estimating exposure exceeding a ratio of 2 to 1 will result in either underexposure or overexposure. That is, the scene exposure range is only 2. It has been found by experience that in general even amateurs who have had long experience can not estimate so closely as this, which no doubt accounts for so many poor negatives. For wider brightness ranges, the scene exposure range diminishes and correct estimates of exposure become increasingly difficult. It is obvious, therefore, that some means of correlating brightness and film ranges is necessary for the best work, and it is for this purpose that the present exposure meter was developed.

## THE EXPOSURE METER

The meter consists of two parts: (1) a means, previously described, of measuring the average brightness of an entire scene or the brightness of any object in it, and (2) a simple calculator for translating the measured brightness into the proper diaphragm apertures (stops) and shutter speeds for correct exposure.

The photronic photoelectric cells are arranged in tubular depressions in the back of the case, as shown in Fig. 2. Extended tubes might have been used to limit the extent of the scene covered, but following a suggestion by D. R. White of the Du Pont Film Mfg. Corp., thin metal partitions were used. These were designed to limit the view to a cone having an angle of about 60 degrees.

The cells are connected in parallel to an electrical indicating instrument of the permanent magnet movable coil type. Advantage

is taken of a very interesting property of the photronic photoelectric cell. Its resistance increases greatly as the incident illumination is decreased, so that a sensitive instrument having a very high-resistance movable coil may be used. As the cell resistance is so high near zero light intensity, the instrument resistance has little effect upon the current output for low intensities. As a result the scale is expanded at the low end where sensitivity is required. This

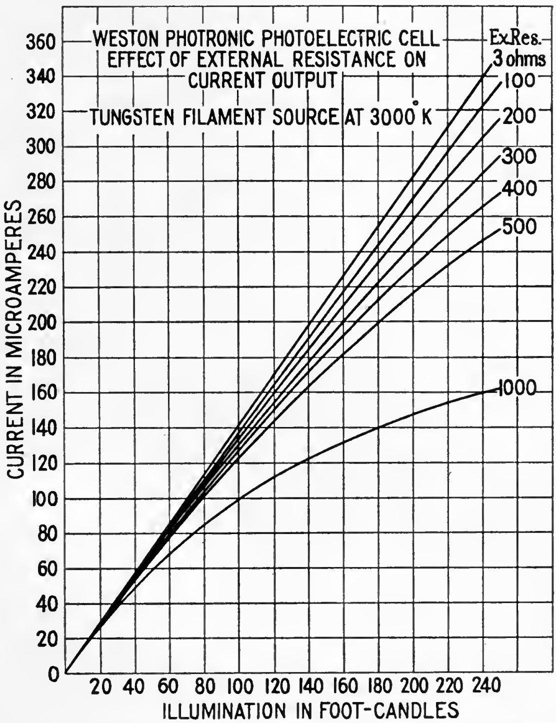


FIG. 5. Curves of current *vs.* illumination for photronic photoelectric cell.

effect is illustrated in the current response curves of the cell for various external resistances shown in Fig. 5. It will be noted that the current for low intensities is nearly independent of the resistance.

### THEORY OF THE BRIGHTNESS METER

Let $M$ in Fig. 6 be a surface of any shape, plane or curved, and at any angle relative to the photoelectric cell $P$, limited only by the

requirements that it must be a perfect diffuser, or practically so, of a uniform brightness of $B$ candles per sq. ft., and that it is of sufficient size and so located that no light enters the photoelectric cell other than that emitted by the surface. The cell is located at the bottom of a tube or its equivalent so as to limit the light incident upon it to a comparatively small solid angle represented by the dotted lines.

Let $A$ be the total area covered by the cell and $dA$ an element of that area. As $dA$ is very small it can be considered as a plane, and

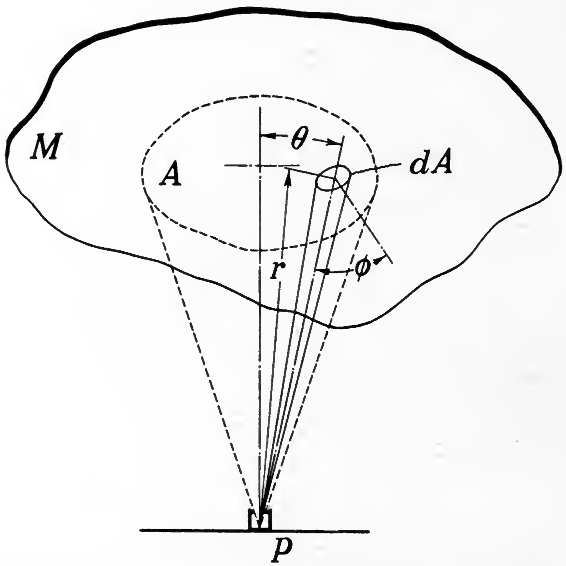


FIG. 6. Light diagram used in theory of surface brightness and photronic exposure meter.

since its brightness is $B$ candles per sq. ft. its light intensity is $BdA$ candles normal to the surface. The illumination at the cell, normal to the direction of the light produced by the area $dA$, is then

$$dE = \frac{B \cos \varphi \, dA}{r^2}$$

where $\varphi$ is the angle that the light beam makes with the normal to the surface, and $r$ is the distance from $dA$ to the cell. This radiant flux entering the cell produces an elementary current $di = idE$, where $i$ = the current produced by unit illumination, say, for 1 foot-

candle normal to the direction of the light, and is a function of the angle of incidence, $\theta$; of the cell arrangement; and of its sensitivity. Then

$$di = idE = \frac{Bi \cos \varphi \; dA}{r^2}$$

But $\cos \varphi dA/r^2$ is the solid angle subtended by the projection of $dA$ in the direction of $r$, or $di = Bi \, d\omega$, where $d\omega$ is this elementary solid angle. Then the current for the total area $A$ is

$$I = \int Bi \, d\omega$$

This shows that the effect upon the cell is independent of the

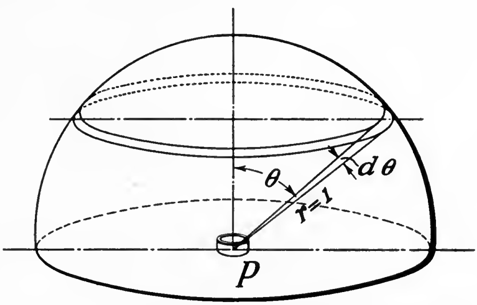


FIG. 7. Hemispherical distribution diagram used in theory of surface brightness.

shape or location of the surface, provided the limitations referred to above are adhered to.

The integral $\int Bi \, d\omega$ can not be evaluated mathematically for the reason that $i$ can not be expressed in general as a function of $\omega$ or of $\theta$. However, it can be changed into a form that can be evaluated from data readily obtained experimentally, as follows:

Referring to Fig. 7, $P$ is the cell that is assumed circular, situated at the center of a hemisphere of unit radius. Consider an elementary circular strip $d\theta$ that has a radius $\sin \theta$, a circumference of $2\pi \sin \theta$ and an area of $2\pi \sin \theta \, d\theta$, since the radius is unity. This is the elementary solid angle $d\omega$ also, since the radius is unity.

Substituting this value for $d\omega$ in equation $I = \int Bi \, d\omega$ we obtain

$$I = \int_0^{\pi/2} 2\pi \, Bi \sin \theta \, d\theta \text{ or}$$

$$I = 2\pi B \int_0^{\pi/2} i \sin \theta \, d\theta$$

This states mathematically that the current $I$ generated by the cell equals $2\pi B$ times the area of the curve having the equation $i \sin \theta$, between 0 and 90 degrees, which can be determined experimentally. It is necessary only to place the cell at a known distance from a luminous source of known candle-power, arrangements being made to change the angle $\theta$ from 0 to 90 degrees. The current per foot-candle is then measured for as many values of $\theta$ as will give a curve whose area is to be computed. Such a curve is shown in Fig. 8.

This curve shows that most of the area is included within an angle

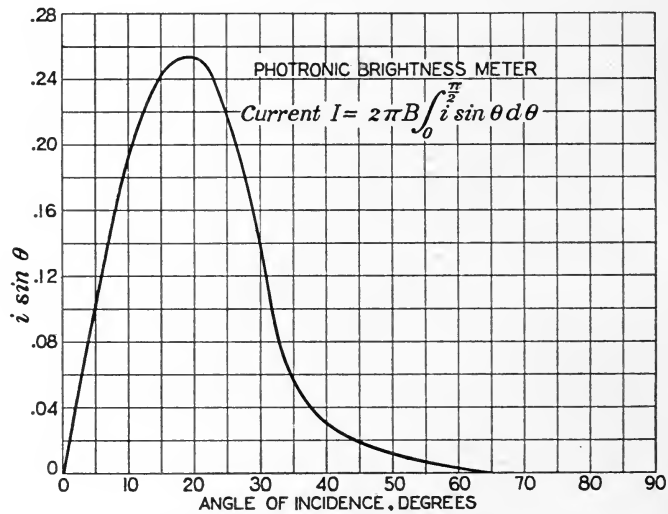


FIG. 8. Current generated in cell of brightness meter by illumination of one foot-candle normal to direction of light, at angle of incidence $\theta$, multiplied by $\sin \theta$.

of 30 degrees from normal incidence and, therefore, for practical purposes, only light coming within this angle is effective in producing an indication. In deducing this equation it is assumed that the cell construction is symmetrical about its axis, which is not strictly true on account of the square-shaped openings.

The area of this curve is a constant, depending solely upon the cell sensitivity and the construction of the parts in which it is mounted and, of course, need be determined but once. Call this constant $K$, and we have $I = 2\pi BK$ or $B = I/2\pi K$ candles per sq. ft.

The electrical instrument, therefore, can be calibrated to indicate

brightness directly. This method is not the simplest one to use but was described to illustrate the principle of the instrument.

Another method of calibrating or checking the instrument in brightness units, much simpler than that just described, is to direct the cells toward a diffusing surface large enough so that no other light enters the cell, of known reflection factor $R$, uniformly illuminated by a luminous source of known candle-power to a measured value $E$ foot-candles. The well-known relation then gives the brightness $B = ER/\pi$ candles per sq. ft.

The ordinary scene, of course, is in general not of uniform brightness and when the meter, calibrated for uniform brightness, is directed toward such a scene, it indicates the average value. Experience has shown that this value when properly used gives in most cases a relatively high accuracy in determining photographic exposure, as will be shown later.

The instrument usually has two ranges, 0 to 1300 and 0 to 130 candles per sq. ft. The high range is obtained by shunting the low range through a contact key, which is normally closed. When the key is depressed, the shunt is open-circuited and the instrument indicates on the low range.

### THE CALCULATOR

The calculator, shown in Fig. 9, consists of three dials, $L$, $T$, and $E$. Dial $L$ is fixed and gives the light values in candles per sq. ft., with numbers from 1 to 1300 corresponding to those on the instrument scale. This dial also contains numbers corresponding to plate speeds.

Dial $T$ is the time dial, graduated in shutter speeds from $^1/_{800}$ second to 64 seconds. It is movable, but requires adjustment only when the kind of film used is changed, as, for example, when changing from regular to super-panchromatic. This dial is held in position by a pin, and to change its position it has purposely been made necessary to lift the dial to the next pin position in order to prevent accidental displacement without the knowledge of the user. It can be set so that its index points to the speed of the film being used.

Dial $E$ is the working dial, and requires but one setting to determine an exposure. This dial contains the scene positions and the stop values, graduated from $f/1.5$ to $f/32$.

The values on the dials and their relative locations depend upon the equation, developed above, for exposure; and upon film char-

acteristics determined experimentally. They are based on the speed of high-speed orthochromatic film, examples of which are *Verichrome* and *Plenachrome*, which is arbitrarily given the number 16. They increase logarithmically, each division having a value, the effect of which upon exposure is approximately equal to $\sqrt{2}$ times that of the preceding one. That is, the effects are doubled for every second division. In the case of the $f$/scale, it is also the effect upon the exposure that doubles every second division; therefore, since exposure varies with the square of the $f$/number these numbers double every fourth division. Any of the scales may be extended in either direction indefinitely by counting divisions, remembering that the effective values double every second division.

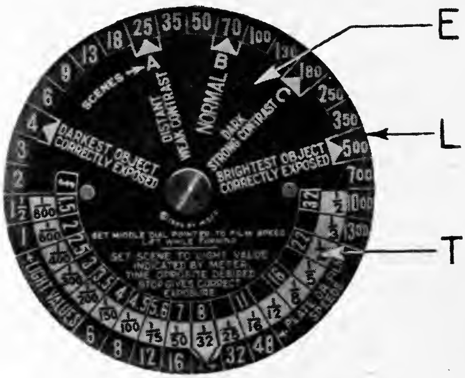


FIG. 9. Mechanical calculator.

It would have been desirable to measure brightness in metric units as is customary in photographic work, but these units gave unwieldly figures for values of brightness occurring in nature. Candles per sq. ft., however, gave values that were satisfactory. A brightness of one candle per sq. ft., for example, will produce a just visible density on a sensitive emulsion in a camera having an ordinary fast lens at the lowest shutter speed for instantaneous exposure.

The calculator is so designed that it indicates the limits of the film range for correct exposure, which lies between the positions marked *Darkest Object* and *Brightest Object*, and provides means for properly adjusting the brightness range of the scene to the film range so as to produce the best exposure. In this manner it takes care of the entire range of light values in the subject.

The position designated *Darkest Object Correctly Exposed** is so located that, when set to any light value, an object having that brightness, when used with the indicated values of stop and shutter speed, will result in an exposure on the plate or film corresponding to the lower end of the straight portion of the characteristic curve. The position designated *Brightest Object Correctly Exposed* in a similar manner, when set to any light value, indicates values of stop and shutter speed which, for objects having that light value, will result in an exposure corresponding to the upper end of the straight portion of the characteristic curve.

This may be visualized by assuming a strip of the photographic film or plate placed around the circumference of the light value dial $L$, and that the dial $E$ is set to any position relative to dial $L$. Then, using the shutter speed and aperture indicated for this position, if the film could be exposed at each light value division on dial $L$ by the light from an object of corresponding brightness, there will result, after development, a variation in density along the strip. This increases in equal increments for the light values lying between the *Darkest Object* and *Brightest Object* arrows on dial $E$, from the minimum correct density at the *Darkest Object* arrow to the maximum correct density at the *Brightest Object* arrow. For light values below and above these arrows the density does not change proportionally, and those portions of the film are in the underexposed and overexposed regions, respectively.

This is true for any position of the dial $E$ when the indicated shutter speed and aperture for that position are used, and thus the calculator provides a means of placing the brightness range of a scene on the correct density range of the emulsion.

### BRIGHTNESS RANGE METHOD

In any scene to be photographed, therefore, if one can measure the brightness of the darkest and brightest objects in which detail is desired, it is necessary only to set the dial $E$ so as to include these extremes of scene light values on dial $L$ anywhere between the *Darkest Object* and *Brightest Object* arrows on dial $E$, and a correct

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* Since this paper was written the designations on the calculator dial have been changed with the idea of making their meaning more clear, as follows: *Brightest Object Correctly Exposed* is changed to *Brighter Objects Will Be Overexposed* and *Darkest Object Correctly Exposed* to *Darker Objects Will Be Underexposed.*

exposure will result, if the indicated shutter speed and aperture are used.

If the dial $E$ is set so that the brightness range comes at the lower end of the film range, then the average density of the film will be low, and it will be a quick-printing film; if the brightness range is set midway in the film range, the film will have a medium density; and if set at the upper part, the film will have the maximum safe density and will be a slow-printing film. This method affords the photographer a means of obtaining exposures of any desired density within reasonable limits.

### DARKEST OBJECT METHOD

It is usually quite sufficient in ordinary scenes to measure the brightness of the darkest object or darkest shadow in which detail is desired if these can be approached sufficiently close to be measured, and then set the *Darkest Object* arrow to the value of the measured light value and adjust the camera to the indicated shutter speeds and aperture.

All objects in the scene will then be correctly exposed up to the brightest objects, provided the brightness of these objects does not exceed the limit of the film range, which is about 128 times that of the measured value of the darkest object and indicated by the value opposite the *Brightest Object* position on the dial. For example, suppose that a building is to be photographed and that it is desired to obtain details in the shadows, which are found by measurement to have a brightness of, say, 4 candles per sq. ft. Then setting the *Darkest Object* position to 4, it will be observed by referring to the dial $E$ that all objects in the scene having a brightness up to 500 candles per sq. ft., if any are present, will be correctly exposed if the indicated exposure is given. This upper value is greater than is usually found in such a scene. When the brightness of the brightest object is considerably less than that indicated as the *Brightest Object Correctly Exposed*, then, as referred to above, the general density level of the film may safely be increased, if desired, by increasing the exposure, provided the brightness of the brightest object in the scene does not exceed the value indicated on dial $L$ as the *Brightest Object Correctly Exposed.*

### SUBSTITUTION METHOD

When the brightness of a dark colored object in the shade is very low so that it can not be measured with accuracy on the instrument,

or possibly not at all, its approximate value may often be determined by the following substitution method:

The object, as, for example, the trunk of a tree in the woods or the side of a dark colored building, usually has one side or a part well illuminated; and if not, similar objects in the vicinity may have. Measure the brightness of the lighter side, then place a white or a light colored surface, such as a sheet of paper of ordinary letter size, on the same part of the surface where the first measurement was made, and measure its brightness. The ratio of the two readings gives the ratio of the reflection coefficients of the paper and the object. Then place the paper on the dark side, the brightness of which is desired, and again measure its brightness. The brightness of the dark object can then be computed by dividing the paper brightness just measured by the ratio found in the first measurement. For example, assume a scene under trees, the darkest object of which is the trunk of a tree, the details of which are to be rendered in the photograph. As is often the case, spots of sunlight illuminate parts of the tree trunk, or that of some similar tree; measurement of a bright spot gives, say, 50 candles per sq. ft. Placing a sheet of white paper on the same spot gives a brightness of, say, 600. The ratio of the reflection coefficients is then 12. Now, placing the sheet of paper on the dark side, and finding it to measure, say, 3 candles per sq. ft., it follows that the brightness of the dark side is 3 divided by 12 or $^1/_4$ candle per sq. ft. The position on the calculator dial $L$ for this value is at the fourth division below 1.

### BRIGHTEST OBJECT METHOD

In very dark subjects, such as interiors, dark ravines, *etc.*, where the darkest objects are so much less bright than 1 candle per sq. ft. that they can not be measured by the instrument, and where the substitution method is not convenient, the brightest object in the scene in which detail is desired may be measured, and the arrow on dial $E$ designated *Brightest Object* set to the measured light value. Then, setting the camera to the indicated stop and shutter speed, all darker objects in the scene down to $^1/_{128}$th the brightness of the object measured will be correctly exposed. In using this method, accidental highlights, such as windows looking outdoors, or sun spots in ravines, *etc.*, should not be measured as the brightest object. This method is limited by the fact that the meter is not sensitive to light values less than about 1 candle per sq. ft., which is the bright-

ness of a white surface placed about 4.5 feet from a 60-watt lamp. This limitation is the result of the otherwise very desirable feature of a small and compact size. However, in such scenes, especially interiors, the photographer usually increases the illumination for better effects and the meter can be used. If no object is bright enough to give an indication, then frequently a sheet of white paper may be properly placed and used as a test object.

### AVERAGE BRIGHTNESS METHOD

There are many situations in which it is not convenient, if not impossible, to approach sufficiently close to the darkest or brightest objects to measure their brightness. In such cases it is necessary to measure the average brightness of the entire scene by directing the meter toward it. In any case, however, the problem is still to determine the brightness range of the scene, and to do this it is necessary to know the ratio of the average value to that of the darkest and brightest objects in which detail is desired. This, however, is the problem for the instrument designer, and is automatically taken care of in the calculator. As the result of experience it has been found that, if all scenes are divided into three classes, this brightness ratio can be predetermined for each class with sufficient accuracy for most practical purposes. The three classes of scenes have been designated *A—Distant or Weak Contrast, B—Normal,* and *C—Dark and Strong Contrast.* Scenes *A* consist usually of those having a high brightness level and weak contrast, such as clouds and distant scenes, and, as can be computed by counting the divisions on dial *L* indicated by dial *E*, Fig. 9, the ratio of the average brightness to the darkest object that could be correctly exposed, if it were present, is 6 to 1.

Scenes *C* consist of dark streets, ravines, *etc.*, where the general level of brightness is low, even at midday, with no bright highlights; and also of scenes where the contrast is extreme, in which the ratio of the brightest to the darkest objects approaches the limits of the safe film range, 128 to 1, where it is desired to obtain detail in the dark objects even at the expense of overexposing the highlights.

For such scenes the calculator provides a ratio of average value to darkest object of 48 to 1.

Scenes *B* represent those not included in *A* and *C*, and are the usual normal subjects. In these the highlights and shadows are not extreme, and are about evenly divided. The calculator provides

for a ratio of average brightness to that of the darkest object of 16 to 1, and a ratio of brightest object to average of 8 to 1.

It may be of interest to know the approximate values of brightness of some of the usual objects in nature. These are given in Table I.

**TABLE I**

*Approximate Brightness of Familiar Objects*

| Objects—near Midday | Candles per Sq. Ft. |
|---|---|
| Clear Blue Sky—Summer | 250– 350 |
| Blue Sky with White Clouds | 400– 800 |
| Sky with Light Haze | 1000 |
| Light Buildings in Sun | 150–1000 |
| Light Buildings in Shade | 20– 40 |
| Green Foliage in Sun | 100 |
| Cement Sidewalk in Sun | 200– 600 |
| Cement Sidewalk in Shade | 30 |
| Average Distant Scenes | 300– 700 |
| Average Normal Scenes | 100– 250 |
| Average Dark Scenes | Up to 80 |
| Under Trees, Dense Foliage | Up to 10 |

## EFFECT OF COLOR AND LIGHT SOURCE

As is well known, the photographic sensitive material is not equally sensitive to all colors even in panchromatic films, and further, the various sources of illumination differ greatly in the relative amounts of the different colors that they radiate. For example, tungsten illumination has relatively little blue and green but is rich in yellow and red rays, whereas sunlight has relatively much more blue and green.

In Fig. 10, curves are given showing the spectral response of the photronic photoelectric cell; the spectral sensitivity of the normal human eye, known as the visibility curve; and the spectral distribution of energy radiated from various sources, all computed to have the same visual intensity by the following method:

Relative spectral energy curves for the corresponding color temperatures were taken from Critical Tables at arbitrary energy levels and the luminosity curves obtained for each by multiplying the ordinates of each curve by those of the visibility curve at corresponding wavelengths. These curves were then integrated by determining the area included under each, to obtain the luminosity from each source, which follows from the equation

$$L = \int_0^\infty E_\lambda V_\lambda d\lambda$$

Where $L$ = luminosity
$E_\lambda$ = relative radiant flux at wavelength $\lambda$
and $V_\lambda$ = visibility function at $\lambda$

In general, these areas will not be equal, but for the same visual intensity they must be equal; therefore, one of the spectral energy curves was assumed as the standard and all the ordinates of each of the others were changed in the ratio of the area of the luminosity curve of the standard to the area of the corresponding luminosity curve of each of the others.

Spectral energy curves drawn with these computed ordinates

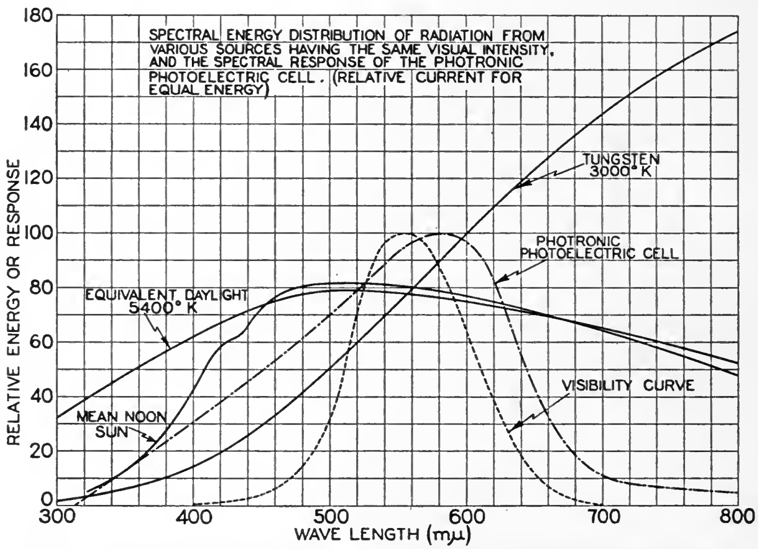


FIG. 10. Photronic photoelectric cell spectral response, and spectral energy distribution of various illuminants of equal visual intensity.

as given in Fig. 10, therefore, all produce the same luminous intensity.

The current generated in the photronic photoelectric cell by the special distribution of radiation corresponding to these curves is

$$I = \int_0^\infty E_\lambda P_\lambda d\lambda$$

Where $I$ = the current generated
$E_\lambda$ = radiant flux per unit $\lambda$ at $\lambda$
$P_\lambda$ = current generated per unit radiant flux at $\lambda$

To determine the current, therefore, it is necessary only to form the current distribution curves by multiplying the ordinates of the photronic photoelectric cell response curve by those of the spectral energy curves at corresponding wavelengths, and to integrate them. This has been done, and it is interesting to find that the three sources, tungsten at 3000°K., mean noon sun, and equivalent daylight at 5400°K., all produce the same current output from the cell for the same visual intensity, within a small percentage, which in the above computation was $2^1/_2$ per cent. This has been corroborated by actual

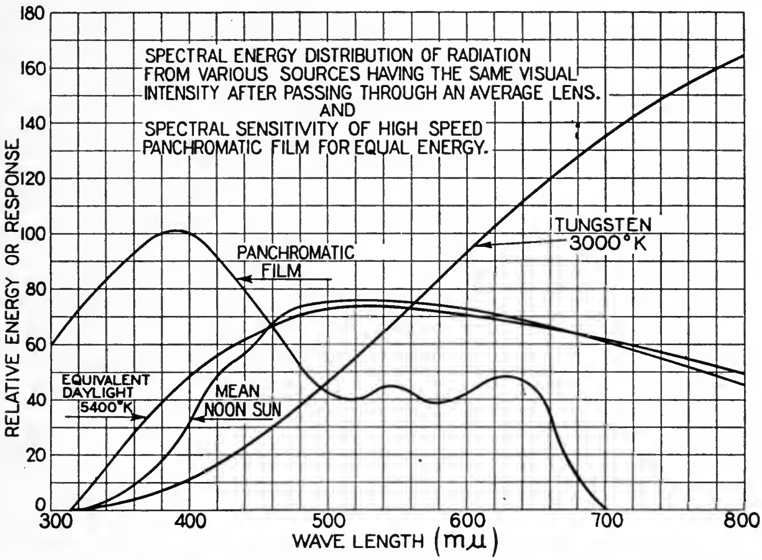


FIG. 11. Sensitivity of high-speed panchromatic film and spectral energy distribution of various illuminants of equal visual intensity, after passing through a lens.

tests for sunlight and tungsten at 3000°K. to within the limits of experimental error.

Fig. 11 shows the spectral distribution of energy from the various sources reaching the photographic film after passing through an average lens. These curves are obtained by multiplying the ordinates of the corresponding curves in Fig. 10 by the spectral transmission of a lens, the values for which were obtained from a paper by L. A. Jones[1] published in the JOURNAL.

Fig. 11 also shows the spectral sensitivity of high-speed panchromatic film as given by Jones.[2] The ordinates of this curve are

proportional to the reciprocals of the radiant energy required to produce a density of unity in the developed negative.

It will be observed by referring to this curve that the human eye is not nearly so sensitive to blues and greens as is the photographic film. On the other hand, Fig. 10 shows that the photronic cell is much more sensitive to these colors and also to the reds, than the eye, and for this reason its indications in an exposure meter are more accurate than estimates by the eye.

In order to compare estimates of exposure by the eye with those by the photronic exposure meter for various illuminants and for various colors, photographic intensities were computed for daylight (mean noon sun), tungsten illumination at 3000°K., and for four representative colors in monochromatic light—blue at 470 m$\mu$, green at 520 m$\mu$, yellow at 580 m$\mu$, and red at 650 m$\mu$. The photographic intensities were computed for two conditions: (1) for equal indications on the photronic exposure meter, and (2) for equal visual intensity, that is, as judged by the eye by photometric methods or otherwise.

The photographic intensities of the light for the same indications on the exposure meter from mean noon sun and from tungsten at 3000°K. for high-speed panchromatic film were determined by multiplying the ordinates of the spectral energy curves by corresponding ordinates of the spectral sensitivity of the film in Fig. 11 and integrating. For monochromatic light, the intensity of the radiation, at the desired wavelengths, required to produce the same indication on the exposure meter as for mean noon sun of the spectral energy level in Fig. 11 used as a standard, was determined by dividing the photographic intensity of mean noon sun as computed above, by the ordinate of the photronic photoelectric cell response curve at the desired wavelength; then multiplying the radiation intensity thus obtained by the sensitivity ordinate at that wavelength of the spectral response of the film.

The photographic intensity for the same visual intensity is determined in the same manner as that just described for equal photronic exposure meter indications, except that instead of using the photronic cell response curve, the visibility or eye response curve is used. The results are tabulated in Table II, and give the ratio of the amount of radiation at each wavelength to that which will result in a film density of unity, compared with daylight as a standard. For example, estimates by the eye for blue will give an ex-

posure four times the correct value, and for yellow slightly over $^1/_4$, or a range of about 16 to 1 in a scene; whereas the photronic exposure meter gives nearly correct values for the blue and red and half or slightly less for the yellow and green, or a range of about 2 to 1 in a scene.

TABLE II

| Color or Source | λ mμ | Photographic Intensity Resulting from Exposure as Determined by: Eye | Photronic Exposure Meter |
|---|---|---|---|
| Daylight | ... | 1.0 | 1.0 |
| Tungsten | ... | 0.81 | 0.81 |
| Blue | 470 | 4.0 | 1.1 |
| Green | 520 | 0.35 | 0.53 |
| Yellow | 580 | 0.27 | 0.41 |
| Red | 650 | 2.5 | 1.1 |

Monochromatic light is, of course, not found in ordinary scenes, as the colors of natural objects are composite, consisting of rather wide wave-bands and usually having a large proportion of white light. The colors selected, however, are sufficiently representative of the visible spectrum to illustrate the difference in results obtained by the two methods. They show that the photronic exposure meter gives indications that, considering the latitude of films, differ relatively little from the true values throughout the spectrum, whereas the eye values vary through such a wide range that they illustrate again how poor the eye is as a means of estimating exposure, even with the assistance of the usual photometric methods.

## FILM SPEEDS

The exposure meter calculator and film speeds are based upon illumination equivalent to average daylight. For other luminous sources the film speeds may be considered as having different values corresponding to the source, the kind of emulsion, and the spectral response of the photronic photoelectric cell, and the calculator may be set to these values.

Owing to the spectral response characteristic of the cell, the speed values to be used with the meter for various illuminants will, in general, not correspond to the relative sensitivities of the emulsion as supplied by the manufacturer of the film, as these are based upon equal visual intensities or upon equal radiant flux. However, as stated above, the speed values for average daylight and tungsten at 3000°K., by a happy coincidence, do correspond.

In a similar manner when filters are used they may be considered as changing the film speed by their multiplying constant and the calculator may be set accordingly.

In Table III are listed arbitrary speed numbers for various types of film, gathered from various sources and from tests, that are the best obtainable at the date of this writing. They are based on the speed of high-speed orthochromatic film, which is given the number 16. These values may require modification as a result of further experience. A very excellent contribution to this subject was made by Davis and Neeland in this Journal.[3]

TABLE III

| Film | Daylight | Tungsten |
|---|---|---|
| Ordinary Amateur | 12 | 4 |
| Verichrome or Plenachrome | 16 | 6 |
| Regular Ciné Kodak Panchromatic | 12 | 6 |
| Super Ciné Kodak Panchromatic | 16 | 12 |
| Commercial Panchromatic | 16 | 8 |
| Super Panchromatic | 24 | 16 |

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# MUSICAL ACOUSTICS OF AUDITORIUMS*

PETER CAPORALE**

***Summary.***—*The author proposes that, on account of the variation in the time between beats in music, more effective rendition of music could be accomplished by varying the time of reverberation of the auditorium or room in which the music is played. The relation between the tempo of the music and the time of reverberation is discussed, with particular reference to the overlapping of the reverberation from one bar of music to the succeeding bar. (Editor's note: The reader is cautioned to distinguish between the technical meanings of terms used in the paper and their meanings in musical parlance; the footnotes should be consulted for the musical acceptations.)*

The importance of increasing the usefulness of enclosures such as sound motion picture studios, recording studios, broadcasting studios, theaters, music halls, *etc.*, by controlling the time of reverberation is being recognized more and more. In all these types of rooms music of some form is performed, and the control of reverberation may add considerably to the artistic presentation of such music. Thus, the effects of large tone or fine definition or articulation may both be achieved by suitable control. The following is a brief discussion of some of the important factors to be considered in controlling reverberation for musical purposes.

Music is a unique art in that a third person (or group of persons) is necessary to convey the composer's thought to his audience. In particular cases it may happen that the third person and the composer are one, as, for example, when Kreisler plays his own compositions. But even in these cases Kreisler the violinist is not the same as Kreisler the composer. In other words, composition and expression are neither the same nor are they simultaneous. To speak of this situation in more familiar engineering terms, we may think of the history of a musical composition as divided into four stages. The first, which we shall call $A$, is the conception of the composition in the mind of the composer. The second, $B$, is the transcribing of this

* Received December 15, 1932.

** Electro-Acoustical Engrg. Co. of America, Philadelphia, Pa.

concept into a form known as the score. The third, *C*, is the transference of the concept from the score to the mind of the player, or interpreter; and the fourth, *D*, the transmission of the concept, by means of sound, to the audience. It must be obvious that in such a complex transition it is rare that a listener will sense the same musical thought (*i. e.*, the same physical sound as conceived originally) that the composer had in mind, and we may therefore speak (rather loosely, of course) of the efficiencies of the various stages of the transition. For example, there are some effects that can not be indicated by the usual musical notation; hence the efficiency of transition *B* is less than unity. Similarly, the score may be ambiguous in certain

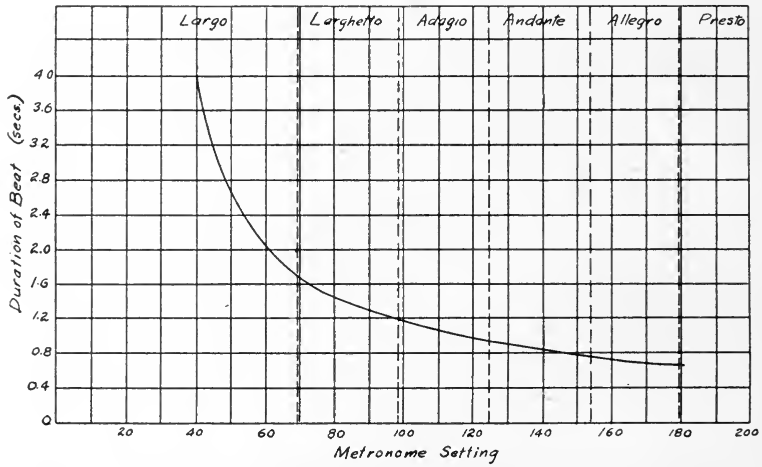


FIG. 1. Duration of musical beats for various metronome settings (*Metronome de Maëlzel*).

parts, or in some respects; therefore, the efficiency of transition *C* is also less than unity. Very little has been done to increase these various efficiencies. Reverberation control, however, offers the possibility of increasing the efficiencies of both transitions *B* and *D*.

The combinations of sound that reach the audience are determined not only by the nature of the source of the sound (orchestra, organ, violin, *etc.*) but also by the character of the enclosure within which the sound occurs and the audience is located. This fact has been known from the most ancient times, but no direct use was made of the knowledge. For instance, when Bach wrote the *Mass in B-minor* he was acquainted quite intimately with the acoustical properties of

the Leipzig Thomaskirche and could foresee the approximate effect of the music. It was obviously impossible for him to foretell the effect in some other church or auditorium. Recent progress in acoustics, particularly as regards reverberation, has made it possible to control the acoustical properties of an auditorium so that a musical composition may be rendered in such a manner as to accord very closely with the wishes of the interpreter. Furthermore, the control of the auditorium might be placed in the hands of the composer, so that not only is efficiency $D$ increased, but also that of $B$; or, more specifically, the composer might indicate on the score just what the acoustical conditions should be for any particular passage.

The technical problem of controlling reverberation is this: given an auditorium having a certain volume and exposed wall surface, to vary the total sound absorption of the room so as to vary its period of reverberation. Several times the idea has been suggested,[1] and in fact, a definite system has actually been proposed, whereby various surfaces of different coefficients of absorption could be exposed.[2] None of these systems, however, could have been readily adaptable to the kind of control required for musical purposes.

The realization of such a scheme, of course, would involve not only the designing of appropriate equipment by the engineer, but, as well, the training of the musician so that he might understand the full possibilities of the system. The latter problem is, of course, not of interest to us here. This discussion will be limited to the musical requirements from an engineering standpoint. It must be noted that in many cases it might not be practicable to vary the time of reverberation during the performance of a piece of music; but it might even then be practicable to vary it *between* successive pieces.

In general, musical compositions may be very roughly divisible into two classes—solo and ensemble, each of which is further divisible into slow and fast music. The crudity of this classification is obvious, but it is at least indicative of the range of types of music. It is rare to find rapid, brilliant passages for one instrument in orchestral works (with the possible exception of solos for the first violin). Music is, moreover, characterized partly by *rhythm*, of which the elementary component is the *beat.** The rapidity or slowness of a passage depends upon the lapse of time between beats. Fig. 1

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* The word "beat" must be distinguished from the common acoustical beat. As here used it has the more common musical meaning, indicating the instant of *beginning* a certain time interval in music.

shows a curve indicating the duration in seconds, between beats produced by a standard metronome. For convenience the corresponding musical terms are also given. Now, since the deleterious effect of reverberation is to cause overlapping of successive sounds, the problem becomes that of reducing the time of reverberation sufficiently to avoid undesirable overlapping. But it must be remembered that not in all cases is overlapping to be completely avoided. If successive sounds pertain to the same harmony, some overlapping is in fact desirable. This, however, is a problem for the composer rather than the engineer.

It will be evident from Fig. 1 that, besides *ease* of control ( a special member of the ensemble may be assigned to the control box with its own score), *rapidity* of control is an important factor in the design of reverberation control equipment. Another determining factor is *range* of control; and finally, the control must be *silent* in operation. These factors are determined by musical requirements. There are also the usual factors of economy of installation, operation, and maintenance, which determine to what extent the other requirements can be fulfilled.

(*A*) *Ease of Control.*—Several reverberation control systems have been proposed or tried,[1,2,3] all of which have been manually operated devices. A notable example is the installation of the National Broadcasting Company in its Chicago studios. It is quite evident, however, that for our purpose we must have recourse to remote control, and by using flexible cables the control box might be one of the instruments of the ensemble. There would thus be a musician "playing the auditorium," under the supervision of the conductor. For organs this would mean additional buttons for its already complex control panel.

(*B*) *Rapidity of Control.*—To understand the problem fully, it will be necessary to consider briefly the musical forms giving rise to it. The required speed is a function, not of the rapidity of the music itself, but of the quickness with which the tempo changes.

As has already been indicated, music is characterized among other things by rhythm, and a composition must for this reason be divided into beats, which are grouped into larger units called *bars*. It is the latter grouping that gives to a passage a large part of its rhythmic character. A waltz, for example, is distinguished by having three beats to a bar, *etc.* But also, and more important from our standpoint, the bar is the unit to be considered in the transition from a

slow to a rapid tempo or *vice versa;* that is to say, the tempo changes from bar to bar rather than from beat to beat, the first beat of a bar coming at the beginning of the bar. In other words, the tempo, or the rapidity of succession of beats, does not usually change within the bar, but *between* bars. For example, in Fig. 2 (upper chart) which is a schematic indication of a sequence of bars, each having three beats *a*, *b*, and *c*, we have the first two bars marked *largo*. From Fig. 1 we see that the time between successive beats for this tempo is four seconds, and hence the length of each bar is twelve seconds. The third and fourth bars being marked *allegro*, the time between beats is only 0.7 second, each bar representing, therefore, 2.1 seconds, or less than one-fourth the duration of each of the first two bars. Similarly the fifth and sixth bars are marked *andante*, with 1.2 seconds between beats and 3.6 seconds to each bar. Let us examine the conditions such a sequence would impose on a reverberation control system.

The first two bars (*largo*) being very slow, the music therein contained depends for its effect on *largeness of tone** rather than on rhythm. The time of reverberation should therefore be comparatively long.** Certainly 3 or 4 seconds (usually a large value for an auditorium containing an audience) would not be too long for these bars. But as soon as we get to bar No. 3 (*allegro*) the bar duration becomes only 2.1 seconds, and the period of reverberation must be reduced to prevent the successive beats from overlapping. Actually, whether the indicated time of 3 or 4 seconds is too long or not, is determined by the music itself. For the case referred to, this time would cause two successive beats to overlap. This is permissible and even desirable in those cases where the successive beats form part of the same "harmony." In other cases, the time would naturally have to be shorter. The time mentioned, however, is intended only to indicate the possible range, and is not necessarily correct for all music marked *largo*. The actual value must be determined by

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* *Largeness of tone* is concerned mainly with amplitude of sound as opposed to rhythm. A full definition would involve considerations of musical tradition and custom, as well as an analysis of psychological reaction to sound. *Largeness of tone* involves not only the amplitude of the sound, but the wave-form as well. Thus, we hardly speak of the largeness of tone of the oboe, or tympani, or cymbals; but we do speak of the largeness of tone of a cello or bass viol, or of the viola, or violin, or of some of the wind instruments. The vernacular of music contains many terms that are perfectly clear to musicians, but yet defy simple and concise definition for the layman.

** In such cases, the harmony also warrants long reverberation time.

the composer who has been taught reverberation control and its principles. In addition, it must be remembered that as the duration of a bar decreases, the music usually depends more and more on rhythm and definition. This requires a still shorter reverberation time, and for bars No. 3 and No. 4 its value will have to be of the order of 0.5 second for best effects. In bars No. 5 and No. 6 we are again permitted to increase the reverberation time, but in this case to about 1.25 seconds (the optimum in all cases will obviously depend upon the nature of the music itself). There is one difference between these two changes. In changing from bar No. 2 to bar No. 3 we had to make the change *before* the beginning of the third bar

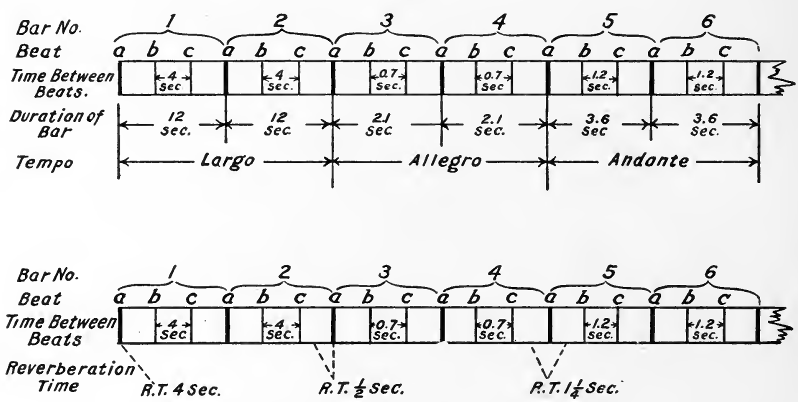


FIG. 2. Above: chart showing the relation between the intervals between beats and the duration of the bar for different tempos. Below: chart indicating the manner of changing the time of reverberation when the tempo is changed.

to avoid bad effects in the more rapid passage. This means that the end of bar No. 2 must be borrowed for this change, and if the change can be made in 2 seconds it will not be noticeable (the duration of the last beat of bar No. 2 being 4 seconds). In changing from bar No. 4 to bar No. 5 we should, analogously, borrow time from bar No. 5 which is slower; but it is a fact that most music is so arranged that the transition from a rapid to a slower tempo is never sudden, passing through a *rallentando* or gradual slowing up. Hence, the conditions imposed by this change are never severe, time being available from both bars. Since the power requirements of the control system are determined by the rapidity of the control, we may say

that it is the change from slower to more rapid tempo that is the controlling factor. From a consideration of the musical literature we may state that the time of change from maximum to minimum reverberation should approach, as a working value, one second. It is evident that economic considerations will determine how closely this value may be approached; a slower control will not be a serious handicap except in certain special musical forms. Fig. 2 (lower chart) shows the same sequence of bars of Fig. 2, with the reverberation time indicated, and a possible way of indicating the interval over which the change may be effected.

(*C*) *Range of Control and Silence of Operation.*—This is a subject that always arouses comments due to the contradictory require-

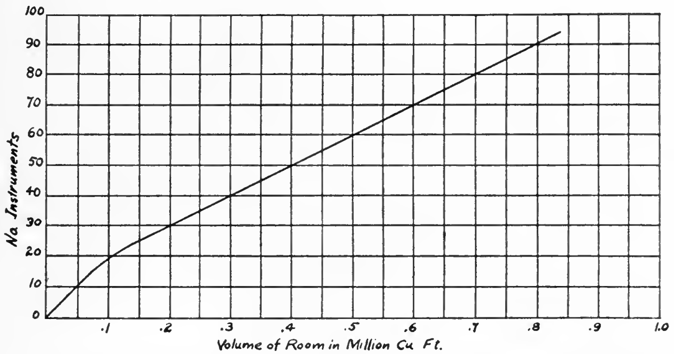


FIG. 3. Approximate relation between size of orchestra and volume of auditorium (from information given in Circular 300, U. S. Bureau of Standards, 1926).[4]

ments of large tone and good articulation. The writer's experience with outdoor concerts, however, has shown beyond a doubt that maximum absorption is most desirable for passages requiring good articulation. In general such passages do not require large tone but only *crispness* and *brilliance.* The ill effects of open-air theaters are evident only in slow movements where the chief emotional medium is tone. For a given size of auditorium the maximum value of reverberation time will be limited by the audience, the orchestra personnel, and the wall surfaces; similarly, the minimum value will be limited by the maximum obtainable absorption in the given volume, though this lower limit is less definite than the upper limit. These limits prevent the same absolute range of control from being applicable

in all cases. However the control equipment should be calibrated in time units for uniformity and to minimize troubles in scoring. Most concert halls designed for the same size of orchestra should have similar characteristics; hence, the above-mentioned limitations imply simply that the scoring for the control should depend on the size of orchestra, just as at present there are different arrangements of the same composition for different sizes of ensembles. For convenience the approximate relation between the size of orchestra and the volume of the auditorium is shown in Fig. 3.[4]

One thing is to be pointed out relative to this use of reverberation control. It is the use of absorbents having approximately flat frequency characteristics. In other words, if a control key represent a reverberation time of $T_1$, say, for the notes of a piccolo, it must represent the same time* for the notes of a bass tuba or a bass viol. If this is not the case, it is possible to score correctly provided the actual frequency characteristic is known, but this introduces undesirable complications, inasmuch as two halls possessing different frequency characteristics would require separate scoring.

The silent operation of the equipment is, of course, necessary to avoid disturbing or distracting factors during the rendition, and is an end to be attained through the proper mechanical design of the system and the proper sound-proofing of the prime movers.

*Use of Reverberation Control for Solo Work.*—It has already been pointed out that, except for organs, the instantaneous control of reverberation by instrumental soloists is impracticable. The best that can be done in such cases is to provide the best *average* reverberation time for the given composition; this is a problem for the musician, not the engineer. It is interesting to the latter to know, however, that having met the requirements already outlined, he will have covered the requirements for solo work which, therefore, does not require his special attention.

* Note that this does not refer in the least to the desirable characteristic of an auditorium having no reverberation control. Several investigators have already studied this problem. What is referred to here is the fact that a given key or switch on the reverberation control box must, if it is marked $T_1$, produce that reverberation time under any circumstance. If then, it is desirable to have a reverberation time, $T_1$, for the bass viol, and a time, $T_2$, for the piccolo (other conditions being equal) then, that means that $T_2$ should be called for when the piccolo is playing and $T_1$ when the bass viol is playing. The case of ensemble is more complex, and as to what is the optimum time for a given passage involving certain given instruments is a problem to be analyzed separately.

*Conclusions.*—To sum up the basic requirements for a reverberation control system for the continuous control of auditorium acoustics from a musical standpoint, we have:

(*a*) Ease of operation.

(*b*) The time required to pass from maximum to minimum reverberation should approach one second; a value less than this would impose too severe economic requirements.

(*c*) The range of control should be a maximum, and be covered by steps, the number of which should be experimentally determined.

(*d*) The operation of the equipment must produce no disturbing or distracting noises.

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# A NEW WESTERN ELECTRIC DOUBLE FILM PORTABLE SOUND RECORDING SYSTEM*

C. R. DAILY**

***Summary.***—*A description is presented of a complete new Western Electric double film portable recording system recently perfected by Electrical Research Products, Inc. The equipment is mounted in a trunk and is designed to be used for location, industrial, and educational recording where portability is of the utmost importance. Entirely new designs of the system amplifier, noise reduction unit, d-c. interlocking motor system, double film recorder, and other units have been perfected. The improved moving coil microphone, permanent magnet light valve, and many other recent equipment developments have been used. The minimum weight of the simplest sound recording channel of this new type is approximately 325 pounds. By adding other units, sound recording systems of any degree of elaborateness may be established.*

Portability and reliability of picture and sound equipment determine the limitations of the talking picture screen. While the field of action of the motion picture camera is practically unlimited, its usefulness has been materially enhanced by the development of highly portable sound equipment. The first sound recording channels used on location consisted of apparatus of the fixed-channel type remounted and placed on trucks. Such channels, while very useful, clearly demonstrated the need of still lighter and more portable equipment. Later came the channel consisting of individual units mounted in trunks, which could be used on locations not accessible to the sound truck. The latter form of equipment has proved to be more generally useful and for that reason has been more intensively developed than any other.

This paper presents a description of a new double film trunk channel for recording which, on account of its light weight and ease of operation, overcomes the many objections found in earlier designs and fills a very definite need on the part of the studios and others who have need of portable sound recording facilities of the most advanced design and highest order of flexibility.

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* Received November 30, 1932.

** Electrical Research Products, Inc., New York, N. Y.

Some of the new developments that have made possible the design of this improved channel are as follows: The moving coil microphone is lighter, more sensitive, and less subject to adverse weather conditions than the condenser type of transmitter. The permanent magnet light valve and modulator unit are much smaller and more sensitive than the light valve assemblies formerly used, and have made possible a much lighter and more compact amplifier and battery assembly. The entirely new d-c. interlocking motor system requires a minimum of power to operate, and provides reliable speed control for all cameras and recorders. New and lighter transformers have reduced the weight of the speech system, while new vacuum tubes have increased the carrying capacity and reliability of operation of the amplifiers, at the same time allowing for a considerable reduction in both $A$- and $B$-battery consumption. Improvements made in the noise reduction amplifier and control unit materially reduce the weight of this part of the equipment.

## GENERAL DESIGN FEATURES

A strong, but light, welded duralumin case is used to contain this new trunk channel, each complete case weighing less than 90 pounds. Specially impregnated insulation has been used in the wiring to prevent deterioration in warm, humid climates. Considerable care has been taken to reduce the number of connections and simplify the control, and yet assure ease of set-up and reliability of operation in the field.

A complete sound recording channel consists of four distinct groups of equipment: sound pick-up devices, amplifiers, film recorders, and motors, with their associated sources of power. The details of design of each of these units have been carefully studied and the operation of the assembly of units considered as a whole so that a unified system could be provided.

The following tabulation lists the various units that have been designed for these recording channels. Several groupings of equipment are mentioned in order to illustrate the flexibility of the channel in building up systems to meet varying recording needs:

**1. Pick-Up Devices**

(*a*) One or two moving coil transmitters connected directly to the main amplifier. Either transmitter may be used at a time. No external transmitter amplifiers required.

(b) One or more moving coil transmitters or condenser transmitters with single- or two-stage transmitter amplifiers connected to an extension 3-dial mixer and volume control cabinet. This mixer connects by cable to the main amplifier.

**2. Amplifiers**

(a) The main amplifier provides in one cabinet all the gain required for the operation of this channel with a single moving coil microphone pick-up.
(b) The same amplifier is also used with the extension mixer mentioned above for multi-microphone pick-up and mixing.
(c) The noise reduction amplifier and control unit derives its input from the film recorder and may be used if desired.

**3. Film Recorders**

(a) A new film recorder using the permanent magnet light valve and carrying the necessary lamp controls and motor switches is available for the double film channel. Split beam photoelectric cell monitor is available with this recorder.

**4. Power Supply**

Three fundamental motor systems are available for use with this channel:
(a) Standard interlocking motors to be used with the present distributor system.
(b) A new type of double wound d-c. interlocking motors with manual speed control. Speed may be controlled automatically by adding a special control cabinet and a generator-distributor case. A maximum of three picture cameras and the film recorder may be used with this system. Twelve-volt storage batteries are the only source of power required.
(c) Synchronous induction motors operating from a 50- or 60-cycle, 3-phase, 220-volt power supply.

Fig. 1 shows the simplest arrangement of the double film recording system. A moving coil microphone, amplifier, film recorder, camera, two motor switch boxes, three 12-volt battery boxes, and the necessary cables make up the entire channel. The speed of the interlocking double wound d-c. motors is manually controlled. The sound equipment by itself weighs approximately 325 pounds, and the picture camera and its tripod, motor, battery, and cable, 170 pounds, making a total of 495 pounds. Additional cameras may be used with this set-up if desired.

Fig. 2 shows a more elaborate double film recording channel having an extension mixer for three-microphone pick-up and mixing, order wire, photoelectric cell monitor, and provision for automatic speed control of the motor system of the film recorder and one or

more cameras. This form of the channel would be satisfactory for heavy duty location work with a large company. The speech equipment and motor system complete weigh approximately 850 pounds, while the cameras and their auxiliary equipment weigh, as mentioned before, about 170 pounds each. This channel is shown in schematic form in Fig. 3. As each case weighs less than 90 pounds when ready for shipment, even this elaborate system may be quickly packed on a truck and taken on location. The

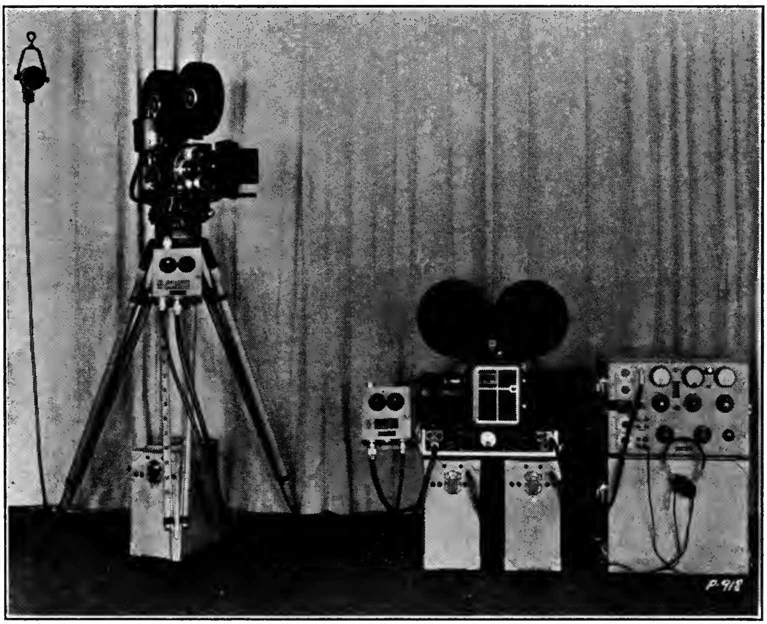


FIG. 1. Minimum complete double film recording system.

entire system may be unpacked and made ready for operation in less than ten minutes by two or three men.

Other arrangements of the equipment are possible, those just described being shown as examples of the flexibility of operation of the system. Thus, wide-range film recording is effected by adding the necessary units of equipment to the system by means of jacks provided in the portable trunk units. All plug and jack connections are clearly marked to facilitate setting up the equipment in the field.

A brief description will now be given of each of the component parts of this system.

### MAIN AMPLIFIER

The amplifier used with this channel is entirely new in design and construction, and has a minimum weight and power consumption. Fig. 4 shows a front view of the case, which is 12 inches deep and has a front panel 19 inches wide by 12 inches high. It weighs 80 pounds

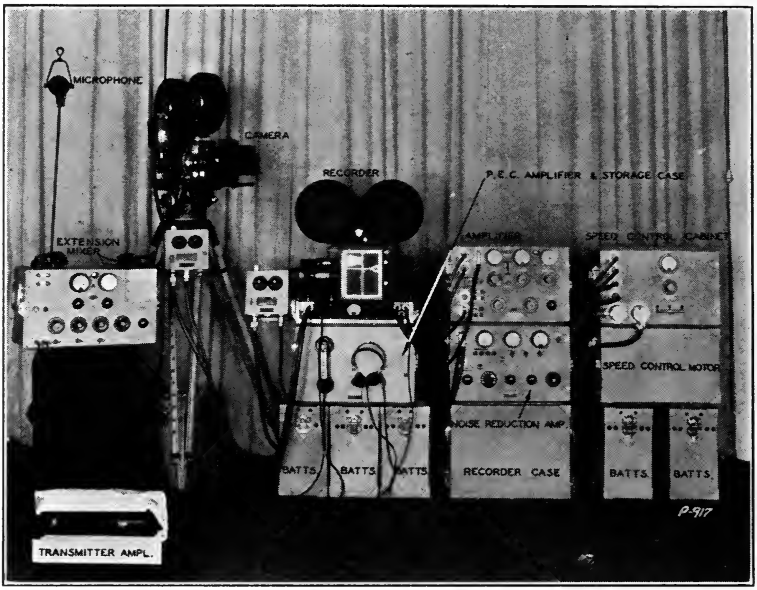


FIG. 2. Double film recording system with extension mixer, noise reduction, photoelectric cell monitor, order wire, and automatic speed control.

complete with *B* and *C* batteries. The shape of this case has been made standard for practically all units of the channel so as to facilitate stacking of equipment. Fig. 5 shows the internal construction of the amplifier.

The speech input to the amplifier is normally taken from the output of one of the new moving coil microphones,[1] obviating the necessity of using a separate transmitter amplifier and polarizing battery. This type of transmitter may be used in humid climates and requires no special precautions such as were required with the

condenser type. This feature should appeal to the sound man who is required to go to locations having difficult climatic conditions.

The maximum gain of the amplifier is approximately 104 db., which is sufficient to modulate fully a permanent magnet light valve used for recording speech out-of-doors at distances of 15 feet to 30 feet from the moving coil transmitter. A volume indicator and headphones are provided for monitoring.

The block of *B* batteries mounted in the main amplifier will operate this amplifier for fifteen to twenty hours, after which it can be easily replaced. This battery life is sufficient for several days'

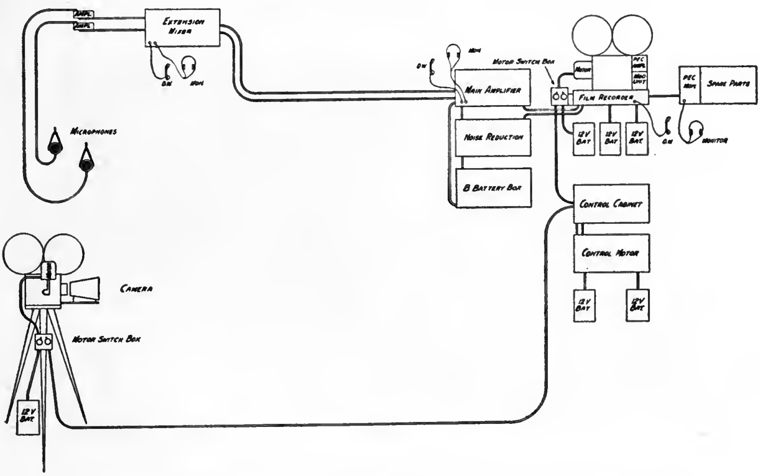


FIG. 3. Schematic diagram of double film recording system.

operation. The filament supply is obtained from the exciting lamp storage battery. A very desirable feature of the system is the fact that the amplifier may be located as far as 400 feet from the recorder and its associated 12-volt lamp battery, as a voltage of only 4.5 is required at the filament terminals. It is also possible to use a cable between the moving coil transmitter and the amplifier 100 feet to 300 feet long, so that a very wide field of operation may be covered.

A special jack is provided for local external *A* and *B* batteries, providing for the use of heavier duty *B* batteries when operating on locations where extreme portability is not required. A special external *B*-battery box for the main amplifier and extension mixer

is available, providing for two sets of 135-volt batteries having a useful life in excess of 100 hours.

The Western Electric 264-*A* vacuum tube is used for all speech transmission services in the system, thereby reducing the number and types of tubes that would normally be carried. Eight of these tubes are used in the main amplifier, the total filament current of which is only 0.9 ampere at 4.5 volts, the total plate current being only 12 milliamperes at 135 volts. These values of filament and plate current represent a considerable reduction from those found in earlier systems, and will assist particularly on expeditions where every pound of weight must be considered. A separate *B* battery is not required for the internally mounted transmitter amplifier;

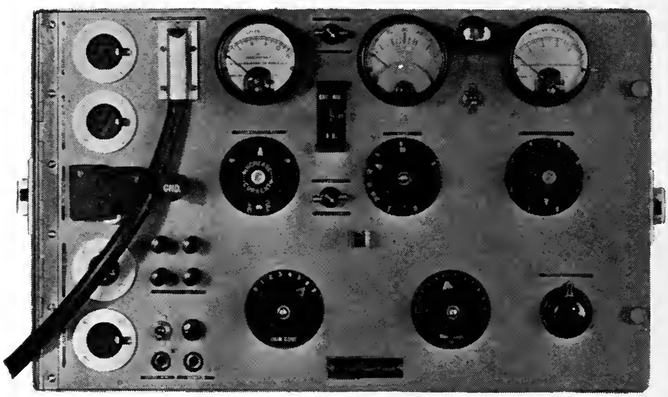

FIG. 4. Portable system amplifier, front view.

this omission effects a considerable saving in weight and maintenance.

Provision has been made for directly reading the filament voltage and plate current of each tube. A jack and key are mounted on the amplifier so that external high- or low-pass filters or equipment for wide-range recording may be connected in the circuit if needed. A speech equalizer is mounted in the main amplifier and can be connected to the circuit by a key. An order wire sub-set has been mounted in the amplifier so that the recordist and extension mixer may communicate with each other.

If pick-up from more than one microphone is required, a simple switching arrangement allows for the alternative use of either of two moving coil microphones. If mixing facilities are required

for several microphones, an extension mixer case is used, which connects directly to the main amplifier by means of two cables.

### EXTENSION MIXER

The extension mixer case is designed to operate from the output of one, two, or three single- or two-stage transmitter amplifiers using either condenser or moving coil microphones. Three mixer dials, a single-stage booster amplifier, a volume control potentiometer, a filter jack, a volume indicator, a headphone monitor extension, and an order wire are provided. The *A*-battery supply is provided by the lamp battery, while the required *B*-voltage is supplied from a separate battery box connected at the main amplifier.

### NOISE REDUCTION AMPLIFIER AND CONTROL UNIT

The value of noise reduction has been clearly demonstrated during the past year. The standard studio type of equipment was de-

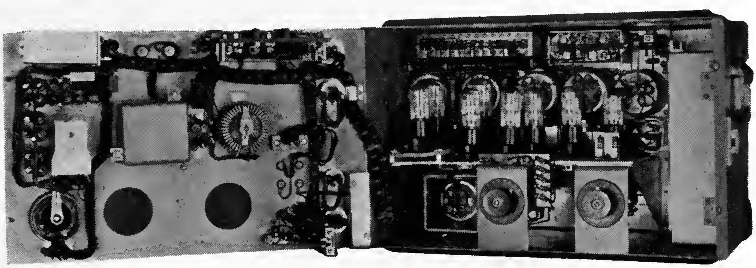

FIG. 5. Portable system amplifier, interior view.

scribed before the Society of Motion Picture Engineers in October, 1931.[2] An entirely new design for noise reduction equipment, however, has been worked out for this portable channel. The principal object in designing a new noise reduction circuit for location service was to reduce materially the weight of this important piece of equipment. A gross weight of only 68 pounds, including tubes and *B* and *C* batteries, has been achieved with no sacrifice in quality. Filament power is obtained from the 12-volt lamp battery, only 0.6 ampere being required. The total plate circuit drain is approximately 18 milliamperes under normal operating conditions, and is provided by a 135-volt block of *B* batteries mounted within the case. One block of these batteries will operate the unit for ten to fifteen hours. These blocks of *B* batteries are interchangeable

with those used in the main amplifier, and may be replaced as a unit in a few minutes. External *B* batteries may be used if desired. The filament voltage, plate current of each tube, and light valve bias current can be read directly.

Both the noise reduction amplifier and light valve control unit have been mounted in one case, and have been so arranged that the necessary adjustments may be made very quickly, thereby facili-

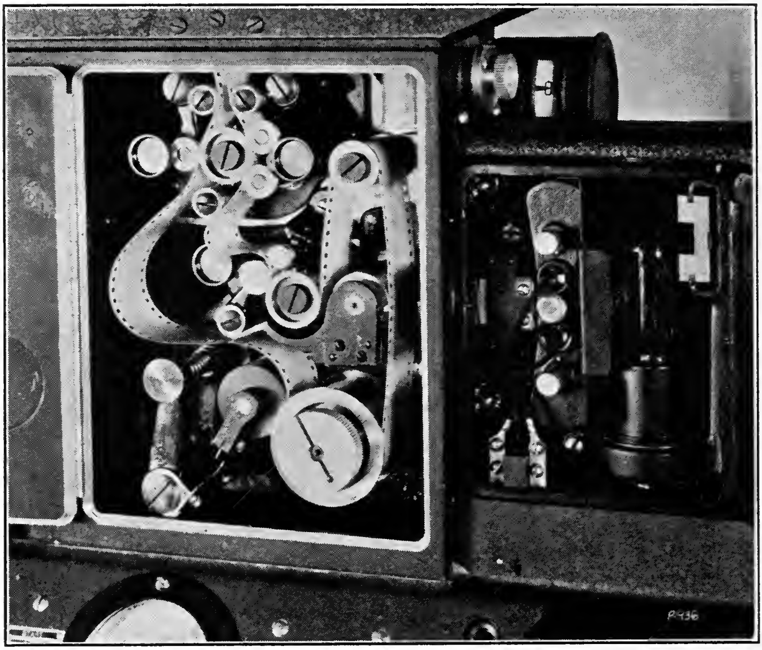

FIG. 6. Film recorder.

tating the line-up of the channel for operation in the field, particularly in cases where it is necessary to get into action in a very short time.

A 1000-cycle oscillator is mounted within the noise reduction case, and is used to adjust the noise reduction unit for cancellation of the bias current and to determine the overload point of the light valve. The oscillator also provides a useful source of tone for general testing purposes.

### PORTABLE FILM RECORDER

An entirely new design of film recorder is used in this channel. A front view of the recorder with the door of the camera and modulator unit open is shown in Fig. 6. The mechanism is mounted in a casting not much larger than a standard motion picture camera and is placed on top of the duralumin base which contains the necessary controls for the recording lamp, light valve, photoelectric cell monitoring apparatus, order wire sub-set equipment, and switches for the motor system. The camera has been designed so that the door can not be closed if any of the guide or tension rollers are not in their proper positions.

A new permanent magnet light valve, recently perfected by the Bell Telephone Laboratories, is used in this recorder. Its use makes

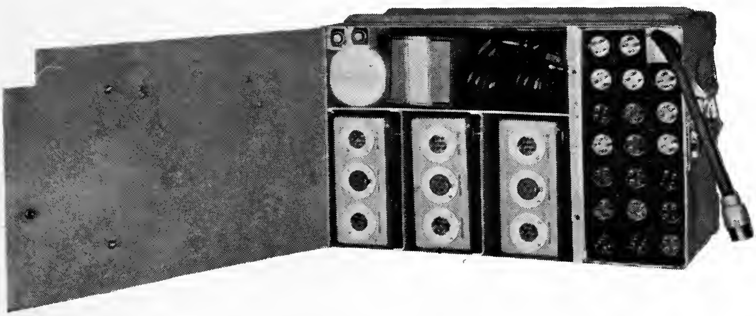

FIG. 7. Photoelectric cell monitor and storage case.

possible a considerable reduction in the size and weight of the recorder, and since it is more sensitive than the standard studio type of light valve, it is possible to reduce materially the battery drain of the main amplifier by using output tubes of lower current capacity than formerly.

The sprocket that pulls the film past the modulated light beam has been carefully filtered. An aperture of the roller gate type is used, and has proved to be very satisfactory. This aperture was first used in the Western Electric studio reproducing machine,[3] and possesses many advantages over the sliding gate formerly used. A tension roller also helps to assure evenness of motion of the film past the light gate.

Photoelectric cell monitoring may be used if desired, since a deflecting mirror is mounted in the modulator so that the modulated

light that does not fall upon the objective lens is reflected to a caesium oxide photoelectric cell. The output of this cell is connected to a single-stage amplifier and a pair of headphones. The output transformer and 90-volt *B* battery for this amplifier are mounted in an auxiliary case, shown in Fig. 7. This auxiliary case connects to the recorder by a short cable, and is used also for storage of some of the motor control units, headsets, handsets, spare light valves, microscopes, tubes, *etc.*

The output of the photoelectric cell amplifier or the direct monitor

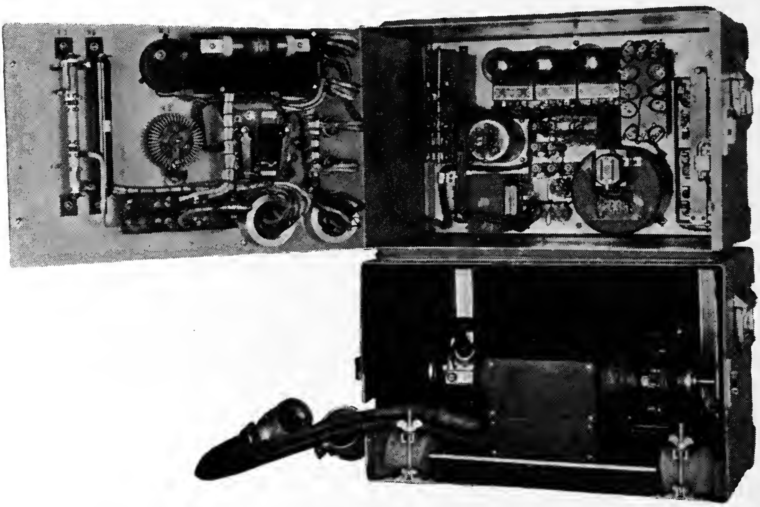

FIG. 8. Motor control cabinet and speed control motor.

may be patched to an auxiliary amplifier to provide loud speaker monitoring facilities if desired.

## MOTOR SYSTEM

Standard interlocking, synchronous, or the new double wound interlocking d-c. motors may be used with this sound recording system. The following section outlines the general operating features of each of these motor systems.

*D-C. Interlocking Motors.*—A new design for the d-c. interlocking of motors has been perfected. The 3-phase winding on the armature and a special type of field construction eliminate hunting and overcome the irregularity formerly experienced with this type of motor

system. Interlocking action between these motors is very positive, but is so designed that it is impossible to burn out the armature or cause destructive arcing of the commutator due to an out-of-phase condition when starting or throwing additional motors on the line. A single 12-volt storage battery is the only source of power required for each motor. By proper design, the danger of burning the commutator at this low voltage has been eliminated and very reliable operation of the motors obtained.

With the double film system and manual speed control, one battery is used for the amplifier, one for the recorder motor, and

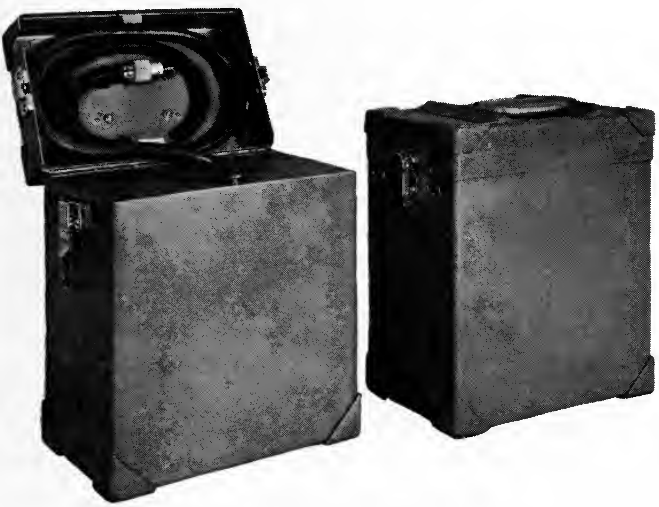

FIG. 9. Cases for 12-volt batteries.

one for each camera that may be required. Thus, the power system can be readily expanded to meet production requirements.

A small switch box containing a field rheostat, relay, and three-position switch is associated with each motor. If the switch is thrown to the "non-synchronous" position each motor may be run independently of the others. This arrangement permits the taking of silent shots at any speed and for the photographing of numbering slates. If the switch is operated to the "interlock" position, all motors in the system may be started simultaneously from any one motor. An "off" position is also provided so that any motor may be readily disconnected from the line.

Three methods of speed control are available for use with the double wound d-c. interlock system. The simplest is manual control of all motors by the recordist, who adjusts and maintains the speed of the system by means of a rheostat while observing a tachometer mounted on the recorder.

Automatic speed control using the same d-c. motors may be obtained by adding a special control cabinet and speed control motor. These units are mounted in separate cases weighing about 55 and 70 pounds, respectively, and are shown in Fig. 8. A 12-volt storage battery for each unit is required to operate this system, and the speed control is equivalent to that obtained with the permanent channel distributor system installations.

Another method of using these d-c. motors is to connect the interlock windings to a public service company's 3-phase, 220-volt line to provide interlock while the power to drive the motor is still provided by 12-volt batteries. Thus synchronous operation is obtained and the speed control is quite satisfactory.

*Synchronous Motors.*—A second type of motor system involves the use of 3-phase induction synchronous motors designed to operate from a 220-volt supply. For portable use this supply may be derived from either the public service lines or from a portable d-c. to a-c. motor-generator set which is available. The d-c. motor of the generator-set operates from a 36-volt battery comprised of three standard 12-volt batteries connected in series, the generator delivering 3-phase power at 220 volts. With this method of drive the motor speed is a direct function of the speed of the motor-generator set which is controlled manually.

*Standard Interlock Motors.*—In existing fixed channels a motor system of the interlocking type has been supplied, which can also be used to drive the recorder and cameras of the portable channel. Standard interlocking motors with special adapters have been built so that they may be connected directly to existing studio motor lines and distributors.

With the three motor systems that are available it is possible to meet any field recording condition. The primary power may be either 12-volt d-c. or 3-phase, 220-volt a-c. The alternating current may be generated either locally or taken from a 220-volt supply line. Speed control may be either manual or automatic, depending upon the requirement of the material that it is desired to record.

### MOTOR BATTERIES

Consideration was given to the idea of using 135-volt, heavy duty *B* batteries to drive the motors when used on location, but it was found that 48 pounds of these batteries would not have sufficient power to pull more than 6000 feet of film through the recorder. Therefore, the replacement and expense of this type of battery would be a major problem on an expedition. The decision to use single storage batteries of the 12-volt, 36-pound airplane type for each motor materially simplifies the field requirements and provides at the same time sufficient power to run over 8000 feet of film without recharging. This battery life corresponds to at least two days of normal operation on location. The batteries are mounted in a duralumin carrying case equipped with a connecting cable and jack. The weight per unit is only 51 pounds. A view of one of these battery cases is shown in Fig. 9. The same type of battery is used for all services in the channel, such as lamp and amplifier filament current supply. A heavier duty battery of the same type is also available. A compact gasoline motor and direct coupled d-c. generator weighing approximately 120 pounds is available for battery charging and will enable the d-c. interlocking system to operate continuously in the field without requiring replacement of batteries.

In conclusion, it can be stated that there has been made available an entirely new group of sound recording units that are capable of meeting practically any requirement imposed on a double film recording system. The various assemblies are light in weight and are of such rugged construction that they may be readily transported to any desired location. The quality of recording obtained with the equipment is equivalent to that obtained with the best fixed channel installations now in service.

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## ENGINEERING AND SCIENTIFIC CHARTS FOR LANTERN SLIDES

*The following material dealing with the principles relating to the control of the effectiveness of graphical presentation of engineering data is abstracted from the American Recommended Practice on the subject which was approved by the American Standards Association on Nov. 11, 1932 (ASA Z15.1—1932). The standard prepared by a sub-group of the sub-committee on Engineering and Scientific Graphs of the Sectional Committee on Graphical Presentation, under the procedure of the American Standards Association, 29 W. 39th St., New York, N. Y. The American Society of Mechanical Engineers took the official leadership in the development of this project. The original draft was presented before the American Society of Mechanical Engineers in December, 1931.*

The recommended practices given below relate to engineering and scientific charts prepared for use as lantern slides. Although certain general principles apply to the entire field of graphics, including time-series charts, computation charts, illustrative diagrams, *etc.*, no attempt is made here to cover such a broad field. Instead, attention has been directed chiefly to general[*,1] and specific suggestions applying to the most common variety of engineering and scientific charts—line charts that show the relation between two variable quantities.

Charts made in accordance with these recommendations are suitable for use as lantern slides, when reduced to one-third their original dimensions. With slight modifications as to line widths,[2] these recommendations are also usually applicable to charts prepared for use both as lantern slides and as illustrations for publication.

### GENERAL

(1) An engineering or scientific chart shown on a lantern slide is only an illustration, presupposes explanation by the speaker, and usually can not be complete in itself.

(2) It should present one central idea, and should be free from all lettering and lines that are not essential to a clear understanding of its message. The number of words on the chart should be held to a minimum (a useful rule is to aim at a total of not more than 15 words, or not more than 20 words if there is a title).

(3) Supplementary data or formulas should not be shown unless

* For reference notes see pages 148 and 149.

absolutely necessary, in which case they should be isolated in position and enclosed by a light line border.

(4) Proportions of about 7 by 10 are suggested[3] for the over-all dimensions of lantern slide charts. In choosing between a vertical and a horizontal rectangle, consider which one presents the material more effectively.

(5) When the amount of lettering is held to a minimum, vertical Gothic capitals are recommended as being highly legible and easy to construct. (See accompanying charts.)

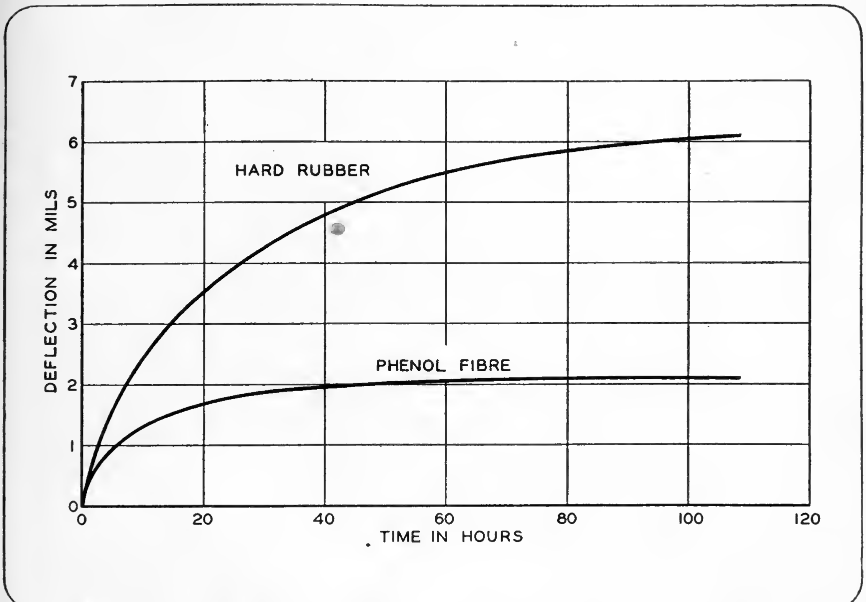


FIG. 1. Original chart for lantern slide (9 × 6$^3/_8$ in., including margins); exactly $^1/_2$ actual size.

For the average lecture hall or auditorium, legibility throughout the hall is obtained[4] if the smallest lettering on the slide consists of capital Gothic letters 0.040 inch to 0.045 inch high, having a line width of about 0.006 inch. It is recommended that in preparing charts for lantern slide use, the original chart be made three times the final lantern slide size, in which case the smallest letters should be made about one-eighth inch high with a line width of about 0.017 inch.[5] (See Figs. 1 and 2.)

For charts with very little lettering that are not to be used for publication, a somewhat larger size of letter is suggested.

(6) In general, a satisfactory lantern slide can be produced by using lettering of substantially the same size throughout. Titles, if included, should be made slightly larger.

(7) All lettering and numbers on a slide should be placed horizontally, if practicable. Any lettering or numbers for which this is not practicable should face toward the right-hand side of the slide.

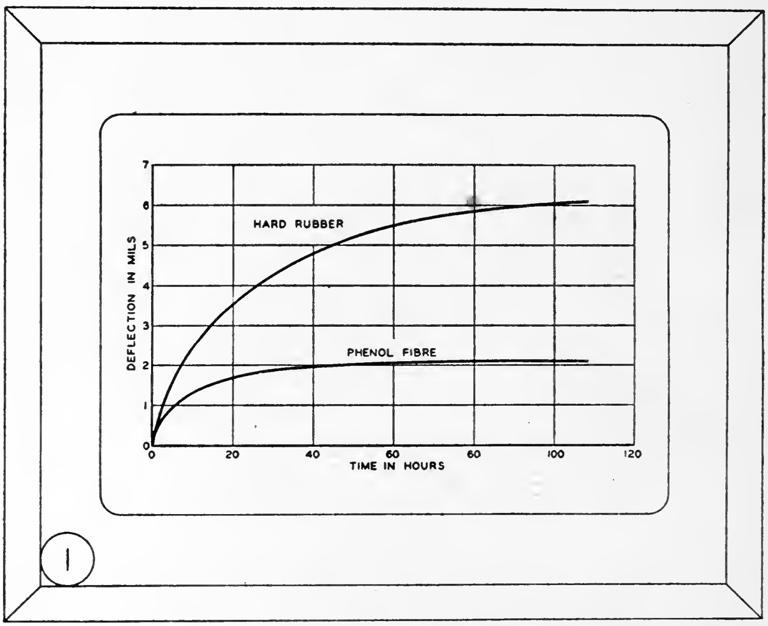


FIG. 2. Fig. 1 reduced to lantern slide size (one-third original chart dimensions). Lettering: height of letters, H-3; width of line, W-2. Lines: curve, $2^1/_2$ points; reference line, $1^1/_2$ points; grid rulings, $^1/_2$ point.

(8) The chart should be precise in execution so as to lend an impression of reliability.

## RELATING TO LINE CHARTS

### *Curves*

(9) The curve is the most important element of a chart and should have the heaviest weight of line[6] to distinguish it sharply from the background.

(10) Ordinarily, not more than three curves should be shown on the same chart. This limitation does not apply to curves that are similar in shape and well separated.

(11) If the curve represent a series of observations, the observed points should be shown, provided that by so doing, additional essential information is given as to the character of the data or as to the reliability of the curve. Observed points should preferably be represented by circles or other closed symbols rather than by

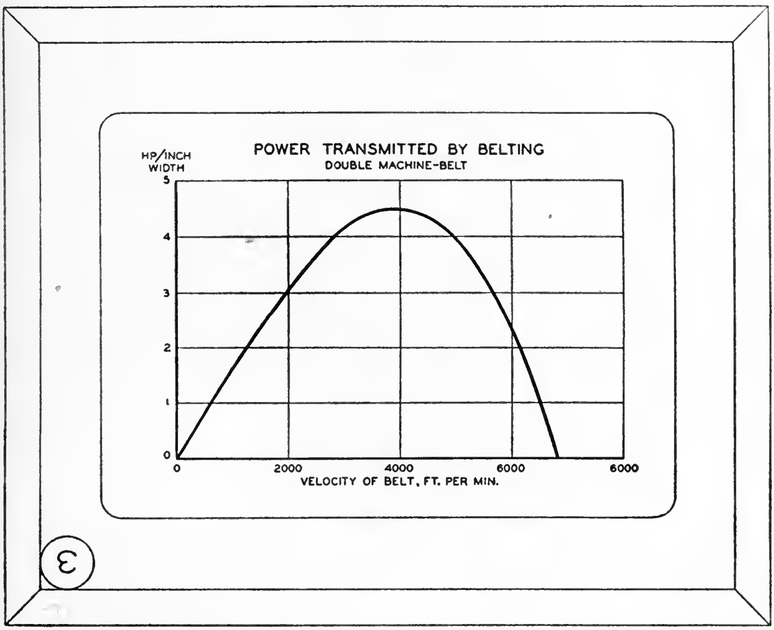


FIG. 3. Another illustration of a horizontal chart. Lettering: title height of letters, H-1; width of line, W-1. Sub-title, scale numbers, scale captions: height of letters, H-3; width of line, W-2.

crosses. For such symbols, a minimum width of line should be used.

## *Grid Rulings*

(12) Grid rulings should be limited in number to those necessary to guide the eye for an approximate reading.

Closely spaced grid rulings are appropriate for computation charts, but not for charts prepared merely to show relation.

(13) Grid rulings, including boundaries of the grid area but

excluding reference lines, should have the lightest weight of any lines on the chart.

(14) Principal lines of reference, such as the zero line, should be made heavier than other rulings but lighter than the curves.

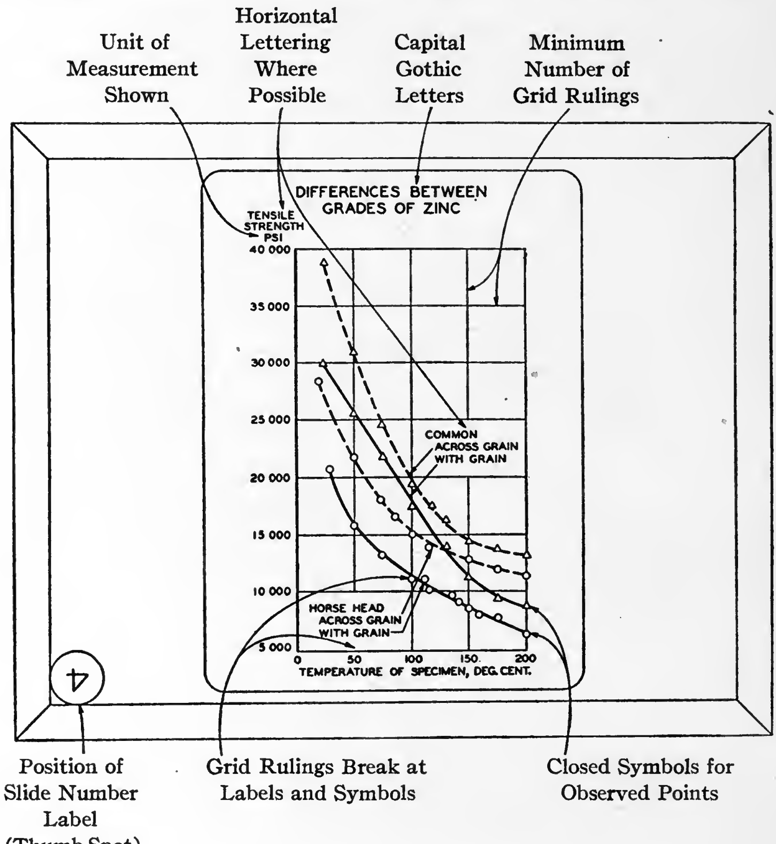


FIG. 4. Illustration of a vertical chart (size of original 6 × $8^1/_4$ in., including margins).

(15) Grid rulings should not run through any lettering on the chart nor through circles representing observed points.

*Scales, Scale Captions, and Designations*

(16) Scales and scale captions should usually be placed at the left and at the bottom of the chart. The scale caption for the verti-

**TABLE I**

*Lettering*

Size of Letters

| *Designation* | *Sample Letters* | *Approx. Height, Inches* |
|---|---|---|
| *H-1* | ABCDE | 0.175 |
| *H-2* | ABCDE | 0.140 |
| *H-3* | ABCDE | 0.120 |

Line Width of Letters

| *Designation* | *Sample Line* | *Approx. Width, Inches* |
|---|---|---|
| *W-1* | | 0.025 |
| *W-2* | | 0.017 |
| *W-2* | | 0.017 |

See the Appendix for information on height of letters and width of lines for several commercial lettering templates and pens.

**TABLE II**

*Line Widths*

| *Lines* | *Printer's Designation* | *Width, Inches* |
|---|---|---|
| | 3 points | 0.042 |
| | 2½ points | 0.035 |
| | 2 points | 0.028 |
| | 1½ points | 0.021 |
| | 1 point | 0.014 |
| | ½ point | 0.007 |
| ○ ● △ □ | ½ point | 0.007 |

cal scale should if practicable be arranged in horizontal lines above the upper end of the scale.

(17) The horizontal (independent variable) scale values should usually progress from left to right, and the vertical (dependent variable) scale values from bottom to top.

(18) The scale caption should indicate both the quantity measured and the unit of measurement.

(19) For arithmetical scales, the scale figures shown on the chart and the space between grid rulings should preferably correspond to 1, 2, or 5 units of measurement, multiplied or divided by 1, 10, 100, *etc.*

(20) Scales should be chosen with a view to making full use of the grid area. When the zero line is a principal standard of reference, it should appear on the chart if its presence clarifies the meaning of the chart.

(21). Curves should usually be designated by word-labels placed horizontally close to the curves, rather than by key letters or numbers. When necessary, an arrow can be drawn to connect label and curve.

## NOTES

*Note 1.*—Attention is called to the possibilities of using negative slides and colors. "Negative" slides (white lines on black background) are less fatiguing to the audience and cost less than "positives"; but should be used only in a thoroughly darkened room. If there be any doubt on this question, it is safer to use "positives."

Appropriate use of color increases the effectiveness of slides. If there is any likelihood of publishing the chart, a black and white original should be used and the coloring done by hand on the slide. A colored original satisfactory for making a colored slide by direct color photography must be redrawn in black and white for publication. Colored slides cost more than black and white ones and the technic is beyond the scope of this brochure.

*Note 2.*—While most publications have their own standards of line widths for engineering charts, the committee finds that the following give results that are representative of good current practice:

(*a*) Line widths on original chart:
   Curves—1$^1/_2$ to 2 points (depending on nature and number of curves)
   Reference Lines—1 point.
   Grid Rulings—$^1/_2$ point.
   (See Tables I and II for examples of line widths designated by "points.")

(*b*) Original charts to be reduced to one-half original dimensions for use as illustrations for publication (and to one-third original dimensions for use as lantern slides).

*Note 3.*—Although slightly more area is possible with proportions more nearly square, the Committee feels that those recommended provide a proper compromise between maximum area, pleasing proportions, opportunity for choice between vertical and horizontal presentation, and use of the same original for a variety of media.

*Note 4.*—The recommended size of lettering and width of line for letters are based on ophthalmological data, actual tests, and an investigation of the conditions under which standard projection equipments are used.

The ratio of the preferred height of letter on the screen to the distance to the farthest spectator is 1:300—that is, 1-inch letter for 25-foot distance, 2-inch letter for 50-foot distance, *etc.* The recommendations of paragraph 5 give this ratio for the following typical conditions:

(*a*) The lens of the projection lantern has a 12-inch focal length.

(*b*) The farthest spectator is at the same distance from the screen as the lantern. (Under average conditions, the lantern is rarely, of necessity, placed closer to the screen than the farthest spectator.)

For these conditions, the width of image of a 3-inch lantern slide opening is equal to $^1/_4$ the distance from screen to farthest spectator. For the exceptional case, the following simple calculation gives the preferred size of letter:

$$\textit{Height of letter on slide, in inches} = 0.040 \times \frac{\textit{(distance, farthest spectator to screen)}}{\textit{(distance, lantern to screen)}} \times \frac{\textit{(focal length of lens, in inches)}}{12}$$

The Committee finds further that the recommended size of lettering is just legible to a spectator located at lantern distance from the screen, if a lens of 18-inch focal length is used.

The Committee has assembled data indicating that slides made according to the recommended practice of paragraph 5 are satisfactory in almost all cases.

*Note 5.*—This is easily done by the use of commercial lettering guides and pens provided for this purpose. The appended table gives, for reference purposes, the height of letters and width of line for several commercial lettering templates and lettering pens.

Where experienced technic is available, modification of these recommendations as to style and size of lettering may be found justified.

In cases where slides must be prepared on short notice, comparable results may be obtained by using pica size typewriter lettering (10 letters to the inch) with an original chart size of $5^1/_4 \times 7^1/_2$ inches, reducing the chart to about 40 per cent of its original dimensions. Although this gives the recommended size of lettering, slides made in this way may be somewhat less legible than those made with the template lettering suggested, due in part to the lesser blackness and sharpness of line for typewriter lettering.

*Note 6.*—The weight of line for a family of curves may be made slightly lighter, and for a single curve slightly heavier than the average shown in Fig. 1 ($2^1/_2$ points). Cf. Figs. 2, 3, and 4.

## APPENDIX*

*Table of Commercial Lettering Templates and Lettering Pens*

| *Templates* Maker | Code | *Nominal Letter Height, Inches* | *Pens* | Code | *Line Width, Inches* |
|---|---|---|---|---|---|
| | "Wrico" | | | "Wrico" | |
| Wood-Regan Instrument Co., New York, N. Y. | VCN–175 | 0.175 | used with | No. 6 | 0.025 |
| | VCN–140 | 0.140 | used with | No. 7 | 0.017 |
| | VCN–120 | 0.120 | used with | No. 7 | 0.017 |
| | "Leroy" | | | "Leroy" | |
| Keuffel and Esser Co., New York, N. Y. | 175C | 0.175 | used with | No. 2 | 0.024 |
| | 140C | 0.140 | used with | No. 0 | 0.017 |
| | 120C | 0.120 | used with | No. 0 | 0.017 |

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* The Appendix is added for information only. It does not form part of the Recommended Practice.

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# BOOK REVIEW

**Photocells and Their Application.** V. K. Zworykin and E. D. Wilson. *John Wiley and Sons,* New York, N. Y., Second Edition, 1932, xv + 331 pp. (180 Figures). $3.00. This book is an extensive revision of the former edition published in 1930. More than one hundred and twenty pages have been added, by including five new chapters and adding considerably to the existing chapters. Important new data have been interspersed throughout the text, the value of the book thus being considerably enhanced for the average reader.

Works on photoelectricity seem prone to one of two extremes. Either so much information is omitted that the book seems sketchy and of limited value, or so much detail is incorporated that reading becomes difficult unless one is an authority on the subject. It seems to the reviewer that the authors have avoided both extremes in the second edition and have produced a work that is very readable in addition to its being useful for consultation with its very complete references and bibliography.

This edition follows the same general arrangement as the previous one. The first two chapters on history and general theory are substantially unchanged. The third chapter on photosensitive films is new and constitutes a short résumé of this important subject. The next two chapters describe the materials and apparatus used and the technic followed in constructing the vacuum and gas-filled cells whose characteristics are described in the succeeding two chapters. Photoconduction and photovoltaic cells are treated much more fully than in the previous edition, where they were limited to one short chapter, now expanded into two. The new dry or *sperrschicht* cells, which have attracted so much attention recently, are discussed under the subject of voltaic cells. The three chapters, ten to twelve, lead the reader from considerations of photo-output and amplifying tubes and the optimum output of various types of cells, through the problem of amplification and carrier modulation by various means. The remaining seven chapters constitute a comprehensive review of such applications as special light-sensitive devices, photometry and colorimetry, sound movies, facsimile transmission, television, miscellaneous uses, and probable future advancement.

E. F. Kingsbury

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# SOCIETY ANNOUNCEMENTS

## BOARD OF GOVERNORS

At a meeting held at the Hotel Sagamore, Rochester, N. Y., January 20, Mr. L. C. Porter, who held the office of President of the Society during 1922, 1923, and 1929, and various other offices since 1917, tendered his resignation as a member of the Board. Mr. H. Griffin was appointed to serve in his stead until the expiration of his term of office.

Extensive discussion concerning the approaching convention to be held April 24 to 28, resulted in conclusions described below under the heading *Spring, 1933, Convention.* Considerable attention was given by the Board to budgetary matters, including sectional and committee appropriations, to the question of dues and subscriptions, and to the general relation between the prevailing economic conditions and the finances of the Society. In order to assist in distributing the JOURNAL among subscribers, a special plan was devised, offering to the first one hundred individuals to take advantage of the plan, complete issues of back numbers of the JOURNAL. Thus, by subscribing for the JOURNAL for 1933 and 1934, at a cost of twenty-four dollars, the first one hundred such subscribers will be entitled to receive a complete set of JOURNALS for 1930 and 1931, without further payment except for postage or expressage. This offer is open also to present subscribers who might wish to extend their subscriptions.

Recommendations made by the S. M. P. E. Historical Committee concerning the requirements for honorary membership were submitted to the Board. These requirements, after further study, will receive final action at the next meeting of the Board, to be held on April 23 at New York, N. Y.

The Board was notified of the formation of two new motion picture societies, namely, the Motion Picture Society of India, and the Magyar Kinotechnikai Társaság. The Society extends to these new organizations its best wishes for success.

Action was taken by the Board on the report of the Committee on Standards and Nomenclature, published in the November, 1932, issue of the JOURNAL, as described below under the heading *Standards.*

## SPRING, 1933, CONVENTION

### April 24–28, inclusive; New York, N. Y.

At the meeting of the Board of Governors held on October 5 at New York, plans for the Spring, 1933, Convention were initiated: the meeting is to be held at New York, N. Y., and of five days' duration—April 24 to 28, inclusive.

Mr. W. C. Kunzmann, chairman of the Convention Committee, assisted by Mr. H. Griffin, chairman of the Local Arrangements Committee, is proceeding with arrangements to hold the Convention at the Hotel Pennsylvania, in the *Salle Moderne.*

Mr. O. M. Glunt, chairman of the Papers Committee, promises an extremely interesting schedule of papers; the number of papers to be presented will be

limited to what can be accommodated in the allotted time without haste or crowding, a feature that will assist considerably in the selection of papers from the point of view of technical quality, with less emphasis on quantity. At the meeting of the Board of Governors on January 20, Mr. Glunt presented a tentative draft of a proposed papers program for the Spring Convention, which, in its general form and with suitable recommendations, was approved by the Board. At a meeting of the Papers Committee to be held in the near future, the proposed program will be put into a more final form, prior to its being mailed to the membership of the Society.

An exhibit of newly developed motion picture equipment will be held, as at past Conventions, which should prove of considerable interest to every one interested in motion picture engineering. Manufacturers of equipment are invited to communicate with the General Office of the Society, 33 W. 42nd St., New York, N. Y., for information regarding the regulations of the exhibit and arrangements for space. Charges for space will be made according to the size of each exhibit and the space occupied by it.

Plans are being made to assist out-of-town visitors to the Convention to pass an interesting time while in New York, and special film programs and trips of interest will be arranged for. Full details of the program, including hotel rates and other pertinent information will be mailed to the members of the Society at a later date. Members and friends of the Society are urged to make every effort to attend the Convention.

## STANDARDS

At the meeting of the Board of Governors on January 20, the report of the Standards and Nomenclature Committee, published in the November, 1932, issue of the JOURNAL, was accepted. In particular, by separate action, the recommendations made in that report, dealing both with 35- and 16-mm. film, were adopted as motion picture standards to be recommended to the American Standards Association, in the requisite form, for its approval.

## CHICAGO SECTION

At the December meeting of the Chicago Section, held at the plant of Jenkins & Adair, Inc., Mr. J. E. Jenkins described the new Phonopticon, a lantern-slide projector employing disk records for sound accompaniment, and the Controllophone, an automatic sound reproducer and equipment demonstrator. A new 35-mm. portable sound-on-film recorder was also demonstrated. At the January meeting, the preliminary report of the Sub-committee on Laboratory Practices, of the Committee on the Care and Development of Film, was read by Mr. R. F. Mitchell, chairman, and carefully discussed by all those present.

## PROJECTION PRACTICE COMMITTEE

A meeting of this Committee was held at New York, N. Y., on January 18. The Committee is at the present time engaged in the study of screen illumination, and is making a series of measurements in a number of theaters that are expected to furnish data representative of the general conditions existing. Another matter upon which the Committee is placing great emphasis is the question of inducing producers to review releases under conditions of illumination comparable with

those found in the theaters, so that prints, when projected in theaters, will not be found too dense to permit adequate screen illumination, although they may have appeared quite satisfactory when projected in small review rooms with a screen illumination several times as great as that obtainable in the theater. Chairman H. Rubin announced that definite action is being taken by producers in adopting the recommendations of the Committee for improving the visibility of change-over marks on films, the recommended marks taking the form of black spots surrounded by clear circles so that they can be easily distinguished by the projectionist against either a light or dark background. The work of collecting data on the clearances, tolerances, and tensions of projectors, begun some time ago, is progressing, and the Committee hopes to have the material sufficiently complete for presentation to the Society within several months. A new test reel is being developed by the Committee for the use of exhibitors in testing the adjustments of their projection equipment. The mere running of this test film in the theater will provide visual and aural means of detecting misadjustments of the optical system of the projector, *etc.*, and will also indicate what adjustments are necessary for the correction of travel ghost, chromatic aberration, sound track adjustments, and the like. The test film will be presented to the Society at the Spring Convention, April 24 to 28, at New York, N. Y.

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## HONOR ROLL

### OF THE

## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

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THOMAS ALVA EDISON
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## PAMPHLETS, BOOKLETS, AND CATALOGUES

Manufacturers of motion picture equipment and supplies are requested to send to the General Office of the Society copies of their descriptive pamphlets, booklets, and catalogues as issued. Notices of the issuance of this material will be published in the JOURNAL, advising the readers that the material may be obtained free of charge by addressing the manufacturers named. This editorial service has been established in order to acquaint readers of the JOURNAL with the commercial developments of the motion picture industry as quickly as they occur.

# JOURNAL

OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

**Volume XX** **MARCH, 1933** **Number 3**

*CONTENTS*

# JOURNAL
### OF THE SOCIETY OF
# MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR



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# REPORT OF THE COMMITTEE ON THE CARE AND DEVELOPMENT OF FILM

## SUB-COMMITTEE ON LABORATORY PRACTICE

*The following report, reviewing the conditions as actually found at present in the field, is intended as an introduction to a more detailed and technical study of laboratory practice, to be reported on later. All the phases of handling and treating both unexposed and exposed film in laboratories are discussed, beginning with the testing of the raw stock as received by the laboratory, passing through the exposing, developing, fixing, washing, and drying of the film and concluding with duplicating and several subsidiary operations. Following the initial work of the sub-committee represented by the studies of existing conditions described in this report, the sub-committee purposes in the future to report separately on each of the above phases.*

### OUTLINE

*A.* Testing
*B.* Exposing
*C.* Developing
*D.* Fixing
*E.* Washing
*F.* Drying
*G.* Conditioning
*H.* Cutting
*I.* Printing
*J.* Duplicating
*K.* Seasoning

### SUMMARY

**Testing.** When producers of motion pictures began to record sound on film in addition to the scenes, the problems of processing became more involved. Factors that had been allowed to vary with impunity had to be maintained constant, and sensitometric equipment, requiring for its operation trained men, had to be installed. New emulsions were prepared in the attempt to obtain a higher quality of picture and sound records.

**Exposing.** The theory of sensitometry is quite explicit in defining the proper exposure of the negative. However, no standard rules of exposure can be strictly adhered to in producing motion pictures owing to the numerous variations in working conditions and the many special effects desired. The greatest degree of coördination is required between the cameramen and the laboratory technicians if the best quality pictures are to be obtained.

**Developing.** In order to increase the quantity of film processed and improve the quality of the product, machines are now used in all large laboratories for developing film. Three methods of controlling the process, or various combinations of these three methods, are usually employed: (1) sampling, (2) time and temperature, and (3) sensitometric. Each of these methods has its own advantages.

**Fixing.** Alum fixing baths are most commonly used, as they require very little attention. The motion of the film through the bath usually causes sufficient agitation of the solution to assure sufficiently complete fixing.

**Washing.** In most instances the tap water runs directly through the washing tanks to the drain. In some few locations it may be necessary to cool the water during the warm season.

**Drying.** Conditioned air of the proper temperature and humidity is circulated through the drying cabinets. The curl of the film usually provides an index of the proper conduct of the drying procedure.

**Conditioning.** To prevent the accumulating of dust and dirt on the film, only conditioned air is admitted into the developing, printing, and assembling rooms. The improvement in the quality of the film, due to guarding it against dirt and scratches, has more than offset the cost of the conditioning equipment.

**Cutting.** The introduction of the sound negative demanded a new technic in cutting and assembling. The addition of music and other kinds of sounds requires thorough technical training of the cutter.

**Printing.** Several types of mechanical devices are now used to determine the proper printing exposure. The uniformity of development that occurs in developing machines is an important factor that assists in properly determining the exposure of the negatives. Trained technicians maintain the exposure scales of the printers constant and uniform.

**Duplicating.** Special emulsions and printers are used in attempting to match the quality of the duplicate print and that of the original print. The contrast can be matched by appropriately developing the film, although graininess may increase and loss of definition occur.

**Seasoning.** Many patented methods are in vogue to protect the film and lengthen its useful life. The most common method of seasoning consists in applying about the perforations a small quantity of wax, which decreases the friction and the tendency to tear during the process of projecting the picture.

It is here purposed merely to describe briefly the methods generally employed by the industry in the development and care of film. Thus, the committee submits this report to the Society with the desire that it be considered as an introduction to the reports to follow, in which the respective operations in this field will be studied individually, both from the standpoint of actual practice and from the existing literature.

At the completion of such a survey of each operation of the producers in converting an emulsion into a finished print, and distributing the print to the exhibitors, the Committee will be in a

position to attempt to make recommendations for the standardization of laboratory and exchange practice.

On examining the bibliography in this field, it was found to be extremely lengthy. Thus, rather than attempt to present a general bibliography in this report, it has appeared advisable to subdivide and list the literature in later reports with the respective operation to which it pertains.

In this general discussion, it may frequently appear that the report includes subjects outside the purview of this sub-committee. However, it was concluded that any factor such as the characteristic of the emulsion or the nature of the exposure that might affect the quality of the finished print should be considered. The quality of the laboratory work is judged by the release print.

### A. TESTING

The proper processing of sound film, when introduced into the laboratories, necessitated an increase of personnel. The requirements of the sound engineers could be correctly interpreted and properly fulfilled only by those familiar with the theory of sensitometry. Some laboratories realized this fact, and either engaged additional help or properly trained some of their own employees. Various types of sensitometers were installed, and sensitometric practice soon became a part of laboratory practice. The film manufacturing companies were particularly helpful in supplying and calibrating equipment and in training the personnel.

After the practice of continually checking and maintaining developers and printers had been instituted, it became apparent that frequently variations were introduced by new emulsions. Checking new emulsions for speed and contrast then became an additional function of the new department.

Various types of equipment were tried, with more or less moderate success. Photocell densitometers were developed for the rapid reading of sound track densities. In most instances, operators have returned to such standard equipment as a calibrated wedge or Nicol prism densitometers. Densities are usually read with the emulsion facing a diffused light. Sensitometric exposures are usually made in variable time steps with a high-intensity light. Unless otherwise stated, all reference made in this report to densities and contrast will imply this type of measurement.

Practically all motion pictures now made in this country are made

on panchromatic negative stock. The process of making film panchromatic consists essentially of adding dyes to the emulsion to obtain the desired spectral response.

With the advent of sound pictures, it became necessary for some producers to replace the noisy carbon lights with silent incandescent lamps. The incandescent lamps, the energy radiation of which was much greater at the longer wavelengths, permitted the emulsion makers to increase appreciably the speed of their product by increasing the sensitivity of the emulsion to the red end of the spectrum. This change permitted a decrease of the required lighting and, in general, resulted in an improvement in quality of the pictures owing to the closer equivalence of the spectral response of the film to that of the eye. However, these advantages are not so important on exterior pictures where many producers continue to use regular panchromatic stock.

The addition of a gray coating to the film base resulted in the absorption, by the base, of the light transmitted through the emulsion, thus preventing the reflection of light back into the emulsion and additional exposure caused thereby. Approximately sixty per cent of the negative emulsions now used employ the non-halation gray base. Emulsion makers are continually improving their product by increasing the speed, decreasing the grain, and adding to the general quality of the finished print.

Due to its low cost and uniform characteristics, positive film is always used for recording sound on a film separate from that containing the picture. Most productions are made by this double system in order to permit the selection of a proper emulsion and negative developer for the sound recording. Numerous new emulsions have been made in attempts to improve the volume and quality of the sound records. Emulsions of high gamma infinity have been made for variable width records, and emulsions with a low gamma infinity have been made for variable density records. High-speed positive emulsions have been made for flashing lamp recording to permit the use of a lower intensity of unmodulated light, thus demanding a smaller polarizing current and tending to increase the life of the lamps.

In single system records, where sound and picture are recorded on the same film, the sound can not be given much consideration. Both the negative emulsion characteristics and the negative development must be confined to those limits that are satisfactory for the

picture. The single system of recording is used only when portability of equipment is more important than high quality of sound. Its chief use is found in news photography, in which the necessary equipment is materially decreased by having to employ only a single camera.

Emulsions for printing are low in price, high in contrast, monochromatic in response, slow of speed, and of extremely fine grain Several hundred prints are frequently made from a single negative. This permits the manufacturers to produce positive film more economically on large-scale production. Film manufacturing losses increase with the speed of an emulsion. Dye sensitization is unnecessary with monochromatic emulsions. It is therefore possible to obtain positive emulsions for a fraction of the cost of negative emulsions.

The positive film must be high in contrast to permit the required over-all gamma of unity to be obtained without excessive negative development. As the high speed of the negative entails a coarse grain, the development is limited to low values of gamma at which the grain is not objectionable.

Lamps of almost any type or intensity can be used in the printing machines. Therefore, economy of manufacture chiefly governs the speed and spectral response of the positive film. The low speed permissible with positive emulsions permits us to realize the advantages of fine grain structure.

### B. EXPOSING

According to photographic theory, the visual tone scale of a scene can be matched on a print only when the negative and print are properly exposed. The region of correct exposure of a particular emulsion can be determined by plotting the characteristic from the density readings of a sensitometric strip of the emulsion. If the density be plotted against the logarithm of the exposure, the region of correct exposure will be a straight line. On a negative picture, developed with a sensitometric strip, those portions of the scene that produce densities that fall along the straight line are properly exposed. Theoretically all other portions are either overexposed or underexposed. This is true also of the print.

In practice, the improper exposure of a negative is easily detected by inspection. If details be lacking in the shadows, the film is underexposed; or, if it be lacking in the highlights, the film is overexposed.

Since it is extremely difficult to reproduce faithfully the complete range of tones visible in the usual scene, the exposure is adjusted for the objects of principal importance. As the time of exposure of all sound pictures must be constant, the exposing light must be adjusted so as to obtain the proper exposure. Trained cameramen seldom fail to expose their film properly when they are working under normal conditions. It is much more difficult, however, to achieve the proper lighting contrast. Often a cameraman returns to a set for the purpose of photographing additional scenes or making retakes after a lapse of several weeks. He must attempt to duplicate his previous lighting so that his new negatives will properly match the previously exposed negatives, both in density and contrast. A change of light intensity in printing can often compensate for a change of negative density, but a change of contrast can be corrected only by varying the negative development.

The usual procedure followed in photographing a scene is for the director to describe to the cameraman the lighting effects desired on the screen when the print is projected. The cameraman attempts to accomplish what the director desires by adjusting the positions of his light sources, the intensity of the light, the color of the light, and the amount of diffusion. These adjustments are based on his experience with numerous scenes photographed under various lighting conditions, which he had subsequently viewed on the screen. The cameraman must be very familiar with the characteristics of both the negative emulsion and the manner of developing in the laboratory. If he makes an error in judging the lighting of the set, the laboratory may or may not be able to help him, depending upon the type of negative development control employed.

There are three principal methods of exposing sound negatives. In the variable width system, a mirror attached to a vibrating galvanometer unit reflects a beam of light upon the moving film, producing a sound track of varying width. There are two methods of exposing variable density sound tracks. In one case, a light beam of constant intensity impinges upon the moving film through a slit, the variation of whose width changes the time of exposure. In the second, the film is exposed to a modulated light beam through a slit of fixed width and the intensity of the exposing light is varied.

In variable density recording, the same rules concerning exposure apply as in exposing a negative picture. Overexposure or underexposure of the sound track causes audible distortion just as similar

errors made in exposing the picture negative cause visible distortion. Improper exposure in variable width recording does not usually result in distortion, but causes a change of volume.

In photographing a scene by the double system, a strict routine is followed to insure the proper marking of the film and thus enable the laboratory to print the sound and picture negatives in synchronism. At a signal from the director, the sound machine and camera are started on an interlocked system. The sound man or his assistant indicates when his machine has reached synchronous speed. The assistant cameraman announces the feature, scene, and "take" numbers before the microphone. Action follows until the cameras are stopped at a signal from the director. With the cameras and sound machine still interlocked, the cameraman and sound man make synchronizing marks on their respective films. The sound man also punches the feature, scene, and take numbers on his film. The cameraman photographs a slate bearing the same information. The films are now completely equipped with identifying marks.

The routine of different companies varies somewhat in obtaining the same results. Some companies, in preference to making synchronizing marks, photograph the action and record the sound of some simple device, such as that made by two pieces of wood struck together. The cutter soon learns to recognize the sound record of this signal noise as a synchronizing mark on the sound track.

### C. DEVELOPING

All developing done by the major laboratories is now accomplished in machines in which the film is mechanically moved through the developer at constant speed. The exposed film is fed to the machine at one end; and the developed, fixed, and dried film is emitted at the other end. Since many of the laboratories designed their own machines to suit their specific requirements, numerous types are found in operation. They may be roughly divided into two classes: those in which the film moves perpendicularly, and those in which it moves horizontally.

The developer is continuously circulated through a cooling system. In some machines thermostats automatically maintain the temperature constant within one degree. The temperature of operation varies at different laboratories from 65°F. to 68°F. The developer is maintained at a given strength by automatically introducing additional developer into the circulating system.

Considerable variation can be found in the speed at which the film travels through the developer in different developing machines. While the average speed for negative film is about sixty feet per minute, speeds as low as twenty feet per minute and as high as one hundred feet per minute can be found at various laboratories.

Similarly, the time of development of negatives varies from eight to twenty minutes, depending upon the agitation, rate of circulation, and strength of the developer. Negative developing gammas vary from 0.50 to 0.65.

Although the negative developers used in different laboratories vary in concentration, their basic constituents are usually identical: monomethyl-para-aminophenol sulfate, hydroquinone, borax, and sodium carbonate. The concentration of these ingredients is varied to permit the most efficient operation of the different machines. When, due to lack of space, a laboratory is obliged to use a small machine, it is necessary to use a fast working developer in order to obtain the proper contrast, unless the laboratory is willing to operate at lower efficiency and operate the machines more slowly.

Three types of control of negative development are in use. In the time-and-temperature system, all negatives, regardless of exposure, are developed for a fixed length of time. The bath is supposedly maintained at a constant strength and constant temperature. The strength of the bath is checked at regular intervals by means of what is supposed to be a standard exposed negative.

In the sampling system, the cameraman submits a sample negative of every new scene, which is developed for a standard length of time. By inspection of the developed sample, the proper time of development of the particular scene is determined. This method places considerable responsibility on the inspector, who must always be in close contact with the cameraman in order to know the type of picture desired.

Sensitometric control is used as a third method of controlling the development of negatives. Sensitometric strips are inserted at frequent intervals to determine precisely the contrast of development and the density obtained from a given exposure. These factors are maintained constant by varying the time of development or by increasing the rate of flow of additional or fresh developer into the circulating system. The usual practice, followed when the contrast or density is found to have changed appreciably, is to vary, first, the time of development. This correction, which causes im-

mediate results, can be realized either by varying the speed of the machine or by changing the length of the film in the developer. This second method of making the correction consists in varying either the lengths of the loops of film in the developer, or in changing the number of loops. The rate of flow of additional or fresh developer is then adjusted so that the developer soon returns to its normal strength. The machine is then readjusted for normal operation.

Due to the numerous adverse conditions that a cameraman must continually face, it is necessary that the laboratory assist as much as possible toward obtaining a good negative. While it is not very desirable, in order to obtain perfect negatives, to have to compensate for excessive or insufficient exposure, it is possible and often practicable to compensate for excessive or insufficient contrast. Thus, in a laboratory in which the sampling method is used, it is frequently possible to match approximately negatives that have been exposed under different lighting conditions. For very flat lighting, the development is increased; and for very contrasty lighting, the development is decreased. Of course, the negative development must not be increased to such an extent as to permit the negative grain to become objectionable. Extreme care must be taken at the laboratory to interpret correctly the lighting effects desired by the cameraman and director. The cameraman should always be advised of any variation made in his favor to aid him in future lighting.

Although positive emulsions are used for variable density sound negatives, they are usually developed in a negative bath. This is a low gamma bath, which permits a reasonable developing time for the desired low contrasts of 0.40 to 0.55. An exception to this occurs when developing negatives recorded by the flashing lamp, in which case the records are frequently developed with the regular prints to a gamma of 2.0 to 2.2. This high negative development tends to correct the distortion due to the underexposure. The volume level of the signal on the print also increases with the negative development.

In variable width records it is highly desirable to develop the negative to the full extent if the maximum volume is to be obtained. Frequently a special high gamma developer is employed, and gammas as high as 3.0 are found.

The usual bath employed in developing prints is of the type employing monomethyl-para-aminophenol sulfate and hydroquinone. The desired contrast of development varies from 1.80 to 2.20. The

permissible variation during operation is approximately five per cent. It is extremely important that the density obtained in the positive bath after a given exposure remain constant. Frequently orders come to the laboratory for reprints of negatives that have been timed several weeks, or even months, previously. If originally the bath had been properly maintained and if the new bath is made to match the original bath properly, it becomes possible to use the old printing cards that indicate the proper printing step for each negative scene. If, on the other hand, the strength of the original bath had been allowed to vary, the negatives made in later baths would require retiming for all reprints and the timer would never be certain of his results.

Sensitometric exposures are usually employed to check the contrast and density obtained in the positive bath. However, a print made from a standard negative and a standard printer is also used as an additional visual check.

Positive developing machines are usually constructed to run at higher speeds than negative developing machines. The printed film is not as valuable as the negative, and in case of damage it can easily be replaced. Due to the brevity of time between completing the photographing of a picture and releasing it, it is usually necessary to operate the positive machines at high speeds in order to adhere to the laboratory's schedule.

The average speed of the positive machines is about 110 feet per minute. Some laboratories develop as much as 150 feet of film per minute, while others develop as little as 80 feet per minute. The temperature of the bath is maintained constant within a degree. The average operating temperature is about 66°F. The time of development varies from three and a half to eight minutes, depending upon conditions.

### D. FIXING

Most laboratories use an acid or a chrome alum fixing bath. An acid bath must be watched so as to guard against precipitation, which may cause an undesirable deposit on the film. In general practice, the fixing solution is neither mechanically circulated nor thermostatically controlled. The temperature of the room and the proximity of the washing tanks are sufficient to maintain the temperature below 68°F. When the temperature is allowed to exceed 70°F., the grain of the film increases and sulfur dioxide may be released. The motion of the film through the solution causes sufficient agitation for proper fixing.

The strength of the fixing bath is checked by noting the point in the machine at which the film becomes clear. When this point approaches the vicinity of the wash tanks, the solution is strengthened by replacing some of it with fresh solution.

The average time of fixing negative film varies from 8 to 12 minutes. Several minutes less are sufficient for fixing positives.

### E. WASHING

Wash water is usually obtained directly from the main supply. In some instances during warm seasons, some rough method of cooling may be required. Normally, however, the temperature of the tap water does not exceed 70°F., which is satisfactory for washing. The water flows continuously from the main into the wash tanks, and thence to the drain.

A chemical test is frequently employed to determine whether the film has been sufficiently washed. The drippings from the film can easily be tested for the presence of hypo by adding a solution of potassium carbonate and potassium permanganate in water. A greenish yellow color results when hypo is present. The average time of washing negative film varies from 10 to 15 minutes. Several minutes less of washing are sufficient for positive film.

### F. DRYING

Since the universal adoption of machine methods of developing film, the drum method of drying is no longer used. By the modern methods, film is dried in cabinets through which conditioned air circulates. The relative humidity of the air is maintained at approximately 40 per cent, at a temperature of about 73°F. In some instances, when the machines are required to operate at maximum capacity, temperatures as high as 110°F. are necessary in order to be sure that the film becomes sufficiently dry. However, it is considered poor practice to operate under such conditions, 85°F. being supposedly the optimal temperature for drying.

The rate of flow of air required for complete drying depends upon the construction of the cabinets, the position of the baffles, and other variables. An operator constantly checks the drying of the film by inspecting the curl of the film through the glass doors of the drying cabinets.

### G. CONDITIONING

Laboratories have found it necessary during the last few years to be equipped with high-grade air conditioning systems. All dust

particles must be removed from the air admitted to the developing, printing, and assembling rooms, and particularly from the air forced through the drying cabinets. The temperature and humidity of the air in the drying cabinets are also maintained constant. Automatic temperature and humidity controls are installed in order to maintain the proper drying conditions regardless of the exterior atmospheric conditions. The temperature and humidity of the air in some of the laboratory workrooms are also controlled; particularly in the printing room, where a relative humidity of 65 to 70 per cent, at a temperature of approximately 70°F., is maintained in order to prevent the static discharges that sometimes occur when exposing raw emulsions.

The cycle of air conditioning is roughly as follows: Air is admitted through a vent into a heating chamber. After a suitable adjustment of the temperature, it is mixed with the air that is being recirculated. It is then forced through an automatic filter into the water spray chamber, where the air is washed and given the proper temperature and humidity. The air is drawn from this chamber, forced into the ducts, and distributed. In addition to this air conditioning unit, a heating system and a refrigerating unit are also required.

### H. CUTTING

After being properly dried, the sound and picture negatives are cut into single takes and properly marked for printing. The marks are so made as to compensate for the approximate 15-inch displacement required by the projector for synchronized reproduction.

A complete list of all takes is submitted to the laboratory by the cameraman. This list aids the cutter in assembling and marking the film, and furnishes advice to the laboratory as to which negatives are to be printed. Numerous takes are spoiled, due to improper action, which are not printed. Rush prints of all desirable takes are usually made immediately following the negative development to permit screening by the director on the day following the photographing. After screening, the rush prints are handed to the positive cutter, who cuts, assembles, and selects the scenes as advised by the director. After all the scenes have been photographed and the rush prints have been cut and assembled into a complete print satisfactory to the director, the print is handed to the negative cutters, who cut and assemble the sound negative to match the rush print. A complete new sample print is then made, which is cut and reassembled until the director and producers are completely satisfied.

The negative is again cut to match the corrected print, and a second sample print is produced. Titles, fades, musical accompaniment, and extraneous sounds are all added before the second sample is printed. If the second sample is entirely satisfactory, the picture is ready for release printing.

Producing companies usually have a production laboratory in the vicinity of the studio and a release laboratory at the distribution center. The second sample print is sent immediately upon completion to the release laboratory, together with the sound and picture negatives. This permits the distributing officials to inspect the picture before making the release prints.

### I. PRINTING

The negatives can be timed and the proper printer step on which to expose a given negative can be determined by inspecting the negative. An experienced timer can determine the step on which the negative should be exposed in order to obtain a high quality print simply by inspecting the density of the negative. However, most laboratories also use an exposing device, either for the purpose of checking the timer or for use in emergencies. Such a device is so constructed as to obtain simultaneously a series of exposures that match, respectively, points over the entire printer scale. Thus, a negative can be timed by printing in such a device, and developing, this short sample strip. The proper step can then be easily determined by inspection. As was mentioned in connection with the developer, the timer must also be advised of the lighting effects in the picture that the cameraman is attempting to obtain.

Most negatives, notwithstanding the careful handling in air conditioned rooms, require a thorough cleaning before printing. Several simple cleaning devices have been tried and some are still in use. Most negatives, however, are still cleaned by hand with carbon tetrachloride. Both sides of the film are firmly wiped with a saturated pad of velvet or some other soft cloth. As the vapor of carbon tetrachloride is unpleasant, drafts are provided. The vapor is heavier than air, so down drafts are recommended. The frequency of cleaning necessary during printing depends upon the maintenance of the rooms and machines. Usually the negatives are cleaned after a dozen prints have been made.

In some laboratories, the printers are fitted with suction devices for cleaning the raw stock. Dust particles or any other particles that

might have been deposited upon the emulsion are removed. The illumination of the modern printing room is more than sufficient for efficient machine operation. Properly filtered light, and white walls, can provide satisfactory uniform illumination without fear of fogging.

Two types of printers are employed in picture printing: step printers and continuous printers. The laboratories using step printers claim that, due to the better contact, the definition obtained on such printers is superior to that obtained on continuous printers. Those using continuous printers may or may not admit this advantage of the step printer, but they state that the increased speed and the ability to print either sound or picture more than compensate for a small loss of definition. Step printers run at rates varying from 20 to 70 feet of film per minute, while continuous printers operate at 65 to 100 feet per minute. The number of breaks, the damage caused by a break, and the wear and tear on the negative increase with the speed of printing.

Approximately half the laboratories have adapted their printers to permit the simultaneous printing of sound and picture films. This requires a second printing aperture and light source, as well as additional incidental equipment. Some few machines have been modified to permit forward and backward printing.

For newsreels, both picture and sound are printed on continuous machines. Usually the picture is printed first, the sound being properly displaced and printed after rewinding. The newsreel negative is cut into lengths of approximately one hundred feet. This permits a number of printing machines to be used, and considerably decreases the time of printing.

### J. DUPLICATING

Many methods of duplicating can be found in practice. Special duplicating stocks have been manufactured to aid the laboratories to produce duplicate negatives that are exact replicas of the original negatives.

A positive emulsion with a lavender base is most commonly used for master positives. The colored base serves to identify the emulsion, and acts as a filter when the duplicate negative is exposed.

A special negative duplicating emulsion is made, which incorporates a yellow dye. The effect of the dye is to retard the penetration of the light, and to cause the image to be maintained on the surface of the emulsion.

In some instances, regular positive stock is used for both master positives and duplicate negatives, whereas in other laboratories the duplicate negative emulsion is used for both purposes. When the identical emulsion is used for master positives and duplicate negatives, it receives equal development in each case. Since the development gamma product of the master positive and the duplicate negative should lie in the range 0.90 to 1.00 in order to reproduce correctly the original negative, the respective development gammas are approximately 0.95.

The latest experimental results indicate that the highest quality duplicates are obtained by using the lavender duplicating positive and the yellow-dyed duplicating negative. The former is developed in a positive bath to a gamma of 1.80 to 1.90, and the latter is developed in a borax negative bath to a gamma of 0.50 to 0.60.

In picture duplicating, step printers are frequently used. Fast printing is unnecessary, and losses of definition are cumulative. Excellent duplicates have been obtained, however, on both step and continuous printers.

Sound records can be successfully duplicated in the same manner as a picture. Many companies prefer to re-record the sound, as a small percentage of the high frequencies is lost in printing, due to poor contact and slippage. In re-recording, it is possible to equalize any desired portion of the frequency range.

### K. SEASONING

Numerous systems are advocated for treating release prints chemically or physically in order to increase the life of the prints and eliminate projection difficulties. When new prints are projected there is a strong tendency for the emulsion to deposit on the tension shoes or aperture plate of the projector. The result is that abnormal forces are caused to act on the perforations, and the film may be seriously damaged. As this difficulty disappears after the print has been projected several times, it is desirable to treat the new prints by some method that will give them the same characteristics as prints that have been projected a number of times.

In one system the gelatin is caused to swell, thus permitting to be introduced into it substances that harden the surface and cause a glossy finish. After receiving such a treatment the film is supposed to be able to resist successfully any normal mechanical attacks. This method of seasoning requires special laboratory equipment, or

the film must be sent to a seasoning laboratory. Several other systems, claimed to effect the same results, involve a patented solution which is added to the fixing bath.

Although some of these systems appear to have merit, most of the laboratories are content with edge waxing and buffing. Sometimes the buffing is omitted, the edge waxing being done automatically as the film emerges from the drying cabinets.

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# REPORT OF THE COMMITTEE ON THE CARE AND DEVELOPMENT OF FILM

## SUB-COMMITTEE ON EXCHANGE PRACTICE

*The following report, reviewing the conditions as actually found at present in the field, is intended as an introduction to a more detailed and technical study of exchange practice to be reported on later. All the phases of handling film in the exchanges are discussed, beginning with the reception of the release print from the laboratories, passing through treating and processing, maintenance and inspection, and including a discussion of the equipment and control of the exchanges. Following the initial work of the sub-committee, represented by studies of the existing conditions described in this report, the sub-committee purposes in future reports to deal separately and at great length with each of these phases individually.*

### OUTLINE

*A.* Introduction
*B.* Laboratory practice
- (*1*) Standard release print
- (*2*) Treating and processing
- (*3*) Capacity of reels
- (*4*) Footage of reels
- (*5*) Mounting of film

*C.* Exchange practice
- (*1*) Maintenance of film
- (*2*) Storing of film
- (*3*) Shipping routines and records
- (*4*) Housekeeping, and control of fire hazards
- (*5*) Equipment
- (*6*) Home office control

### SUMMARY

**Introduction.** In this, the first report of the Sub-committee on Exchange Practice, only some few definite recommendations to the entire industry are made. Included in the report, however, are numerous suggestions that should prove valuable when individual practice permits their application.

**Laboratory Practice.** Many difficult problems in exchange practice could be completely obviated if all laboratory work were correct and complete. Proper seasoning of the film after developing would increase the life of the print. A more uniform picture density and sound volume are highly desirable.

**Maintenance of Film.** New film received by the exchanges should be mounted on perfect reels and properly identified. All film should be inspected and repaired

immediately upon its return from the theater. A complete record should be kept of the condition of each reel of film.

**Storing of Film.** Film should be stored according to the code of the National Board of Fire Underwriters, and all local Boards. Temperature and humidity should be controlled wherever possible.

**Shipping Routines and Records.** All movements of film should be recorded. A more uniform method of keeping records throughout the various exchanges should prove advantageous.

**Housekeeping and Control of Fire Hazards.** The National Board of Fire Underwriters and the Department of Conservation of the Motion Picture Producers and Distributors of America have formed rules for the handling of film. These rules should be strictly adhered to by the film exchanges.

**Equipment.** The desirable types of rewind splicers and other equipment are listed. Automatic splicing machines have been found to be more satisfactory than the hand-operated splicing device.

**Home Office Control.** Proper home office control of exchange office routines produces satisfactory results.

## A. INTRODUCTION

In view of the fact that the film exchanges are inadequately represented in the membership of the Society, considerable research work outside the membership of the sub-committee was found necessary, in order to obtain information on the operating routines of some of the exchange units of the industry.

In the following report, laboratory practice and projection practice have been touched upon only so far as was thought necessary to correlate the work of those phases of the industry and that of exchange practice. Those phases include the preparation, by the laboratory, of the release print for the exchange, and the control by the exchanges of the film while in the hands of the projectionist.

## B. LABORATORY PRACTICE

(*1*) *Standard Release Print.*—By adopting the standard release print, the laboratories have vacated many of the irregularities that formerly confronted the exchanges, but there yet remain other problems to be solved with the aid of the laboratories. The variations of the volume range of sound, and of the density of the printed image of both the sound and the picture, are purely laboratory problems in so far as printing is concerned, although they contribute seriously to the difficulties of the exchanges for the reason that such irregularities are rarely evident until the first screening of the print in the theater, when insufficient time remains in which to obtain a replacement print. Standardization by the laboratories in this respect is highly desirable.

(*2*) *Treating and Processing.*—When preparing a print for the exchange, it is desirable that the laboratory treat it so that:

(1) The pulling or straining of perforations, due to deposits of emulsion on the tension shoes or aperture plate of the projector be eliminated.

(2) The emulsion be so toughened as to resist scratching of the surface of the film as far as possible.

(3) The warping and buckling of the film, caused by the heating of the gelatin by the projection lamp, should be reduced as far as possible.

(4) The pliability of the gelatin and its binder should be as permanent as possible, so that the useful life of the film may be made at least equal to the booking period.

(*3*) *Capacity of Reels.*—A standard size of reel, agreed to and used by both the exchanges and the projectionists, must be adopted for the good of all concerned. The mounting of film in the exchanges on 1000-foot reels for transportation, the subsequent transferring of the film to reels holding from 1500 to 3000 feet of film in the projection room, and the re-transfer to the original 1000-foot reels for return to the exchange represents a great deal of lost motion. Needless time and effort is spent by the projectionist in making such changes. A like amount of time and effort is lost in the exchange inspection room in checking the correctness of the footage and of the heads and tails of the reels.

A large amount of film footage is lost because of this practice, and either all film should be mounted on large reels in the exchanges, or projectionists should be forced to discontinue the practice of mounting two or more reels of film on one large reel.

From an exchange standpoint, the 1000-foot reel is far more desirable, owing to the greater ease with which it can be handled and the greater efficiency with which it can be inspected.

The tensile strength of new film and its elongation properties will permit reels to be doubled under proper working conditions without damaging the film; but when the film has become seasoned the perforation area admits of less elongation than the center of the film and is, therefore, subjected to the entire strain of the traction load of the film in the upper and lower magazines.

The braking surface in the upper magazine, for properly controlling the feed of the film when the double reel is full, causes a tension to be applied to the later footage of the reel that often is greater than the elongation of the perforation area permits. The perforations, as a result, break down.

In the lower magazine, improper adjustment of the friction drive

or the take-up will often cause a similar condition in the early footage of a reel. The variation of the shaft speed of the take-up, caused by the increasing of the circumference of the reel as footage is added to it, is compensated for in a friction drive that must be precisely adjusted to drive the take-up steadily when the reel is filled. The friction required to cause such a steady drive of a full reel is greater than that required for the incomplete reel; whence there results a tendency, in the early footage, for the reel to take the film faster than it is fed out by the lower sprocket.

Insufficient tension on the friction drive of the take-up will halt the loaded reel momentarily, thus creating a slack in the film between the take-up reel and the lower sprocket. This slack permits the take-up drive to operate under no load, and the reel accelerates ahead of the feed of the lower sprocket, tearing the film at the lower sprocket when the end of the slack is reached.

Suggesting a remedy for this, the sub-committee believes that it would be well for the exchanges to consider mounting all film on 1000-foot reels having 5-inch hubs, instead of on the 1000-foot reels with the 2-inch hubs now universally used by the exchanges.

Because of the larger hub, the reel can be made considerably stronger, and a more positive stand can be consistently taken against the doubling of reels by the projectionists. Such a reel would vacate two of the faults of the reel now generally used by the exchanges that most projectionists offer as reasons for doubling reels: namely, a uniform reel for use in the upper magazine, and a reel with a 5-inch hub for the take-up in the lower magazine. This size of reel could be used without materially changing the present shipping cases, vault racks, or equipment in the inspection rooms.

The cost of a strongly built reel with a 5-inch hub would be greater than that of the reel now used; but it is the opinion of the sub-committee that this difference in cost would be more than offset by the probable saving of time of inspection, the elimination of doubling of reels, and the loss of film at the beginnings and ends of the reels.

(4) *Footage.*—The footage of a reel is usually dependent upon the editing of the picture, and can not be controlled by the laboratory; but if a standard approximate length were subscribed to and adopted by the exchanges and the laboratories, the film cutter could be induced to restrict his editing accordingly. A desirable footage under the present exchange operating conditions would be approximately 950 feet per reel, a maximum being set at 1000 feet.

The matter of mounting film on metal reels in the laboratory before shipping to the exchanges, and the shipping of film in metal I. C. C. shipping cases instead of in the wooden cases now used, can be regarded from many points of view. If all film, other than newsreel releases, were mounted on reels at the laboratory, new reels far in excess of the number now bought by the exchanges would have to be purchased, or the return of used reels by the exchanges to the laboratories on the obsolescence and dismantling of film would have to be insisted upon. Such a practice would not offer sufficient advantages to make it worth while to propose it as a standard of general practice.

*Shipping Cases.*—In the matter of containers for shipments: the cost of the wooden cases now used for shipping film from the laboratories to the exchanges is written off after the initial shipment is received by the exchange, as these cases have no further value. The greater weight of the metal I. C. C. shipping case, if used, would increase the carrying charge on the initial shipment so that it would equal the cost of the wooden case. The practice of shipping releases in metal I. C. C. cases would make it necessary to return the cases to the laboratory when final disposition of the film at the exchange is made. If a reclamation plant were established, to which all I. C. C. cases could be sent by all exchanges after final disposition of the film, a considerable saving could be effected for the industry, as a large percentage of the metal cases now junked by the exchanges because of the lack of means of repairing them could be repaired at such a plant for a small fraction of the initial cost. They could then be allotted to the various laboratories for subsequent shipments of new film to the exchanges. Such an arrangement would require a repair plant at both New York and Hollywood, and cases could be sent by the exchanges to either plant by freight or express. A carrying charge of 20 cents would be levied on each case sent from any point in the United States, the express company making a return charge of 20 cents for any container in which an original shipment was made by express.

(5) *Mounting.*—When film is mounted on reels at the laboratory, film bands bearing the title of the subject and the number of the reels should be stamped thereon. When unmounted, it is desirable that the reels be wound with the "tails" outward. A standard size of flange should be used by both laboratories and exchanges for mounting or dismounting film.

### C. EXCHANGE PRACTICE

Exchange practice involves the routine handling of film during its exhibition life, and usually it would appear as though most of the exchanges followed in the main the same operating procedure. A comparison of the condition of the film of one distributor or exchange with that of another shows that such is not the case, and demonstrates the need of standardizing the operating technic of all exchanges of all companies.

In assembling the information obtained from the various distributors on the routine care and maintenance of film, the sub-committee has endeavored to select and suggest for general adoption those features thought most amenable to standardization. Distributing companies that maintain their film in the best condition are those that are completely controlled by their home offices. It seems to be desirable that all distributing companies be similarly controlled. The home office, through its control, should direct the routines of the exchanges in respect to what is described in the remainder of this report, and should hold the exchange managers responsible for the adherence of the exchange to the policies instituted.

(*1*) *Maintenance of Film.*—Film received from the laboratory should be mounted on new reels or on reels that are in perfect condition. A flange made for the specific purpose should be used and film bands bearing complete information should be placed around the film. Film should never be mounted from a flat table, or from a makeshift flange made from old reels. Under no conditions should a pencil or other wooden rod ever be used as a hub or spindle in the center of the reel of film, as a positive fire hazard is created by the friction of the film rubbing against the wood.

A film record card should be made out for each print, on which is kept a record of the condition of the film, its location while in the vaults, full data on playing dates while out of the house, the inspector's initials, and the date of each inspection.

Film should be graded as to its condition in the following manner:

No. 1 condition: good in every respect.
No. 2 condition: good; film damaged slightly.
No. 3 condition: film in poor condition.
No. 4 condition: junk film.

As this manner of grading film specifies film that would be acceptable in any first-class theater as in No. 1 condition, and film unfit for use as in No. 4 condition, the range of conditions between No. 1 and

No. 4 is very wide. New film can be graded only as No. 1, and "junk" film can be graded only as No. 4; whence it follows that No. 2 film is considered to be good film, but its acceptance in a class "A" house would be questionable. Therefore, it is considered good film until the inspector finds out otherwise and marks it as "3," meaning in poor condition. Dirt and oil on the film should not be considered in grading the film, as obviously any grade of film can be dirty or oily, but be restored to the proper condition by cleaning or processing. The sub-committee feels that it is desirable for every exchange to have available a place where dirty and oily film can be cleaned.

Film can be satisfactorily cleaned by cleaning machines now on the market. If done in the exchange, it is impracticable to attempt to clean film by hand. All cleaning fluids should be non-inflammable and uninjurious to celluloid or gelatin. Carbon tetrachloride can be used satisfactorily for cleaning film, as can trichlorethylene, but the use of either requires proper ventilation.

For exchanges that would operate their own cleaning plants, the sub-committee recommends the use of a machine that submerges the film in the cleaning fluid, cleans the emulsified dirt and oil from the film by passing the film through a series of soft rubber squeegees, and polishes it by passing it over revolving rollers covered with soft flannel. The machine and the room should be well ventilated.

Film should be inspected and repaired immediately upon being returned from the theater, and the condition of the film should be noted and recorded on the "film record card." When undue damage has occurred to any part of a print, the record card should carry information of the damage and the name of the theater responsible for it. The booking manager of the exchange should be furnished with complete data on the damage, repairs made, and the replacement parts ordered when necessary.

Inspectors should not be permitted to wear anything on their hands other than a light cotton glove. While inspecting film, all jewelry should be removed from fingers and wrists.

All film should be inspected from the left rewind to the right, beginning with the "tail" of the reel outward, so that the inspected film reel ends on the right-hand rewind with the "start" or head of the reel outward. As all splices are made by scraping the film on the left of the damaged part, this routine results in a splice that is better fitted to pass through the curves and loops and over the sprockets of a

Simplex projector. In splicing, the emulsion should be removed with a dry scraper. Only fresh film cement should be used. A mechanical splice is recommended, and should always be referred to as a "splice" and not as a "patch."

The inspector should hold the film so that it passes first over the left hand and then between the fingers. If held so that the film passes under the left hand before passing through the fingers, all the dirt and grit that is on the film collects on the palm of the hand and scratches the remainder of the reel being inspected.

In order to maintain the proper locations of the "change-over" signals in the standard release print, where these have been altered by placing the film on 2000-foot reels, the "start" mark should always be placed at the correct distance ahead of the action. This distance should be exactly determined in all reels of all prints, and can be maintained by the film footage numbers in the margin of the film. When necessary, black leader film should be inserted between the "start" mark and the first scene of the action in order to maintain the correct distance.

When splices occur at the ends of reels, shortening the distance between the "start-motor" signal or the "cut-over" signal and the end of the action, replacement film should be inserted; or the "start-motor" signal or the "cut-over" signal should be removed, making new ones at the proper distance from the end of the action in order to provide the projectionist with the correct "cut-over" cues. To avoid mutilation of the film by punch marks, stickers, and scratches, exchanges should notify all exhibitors that the only permissible way of indicating variations from the standard release print markings would be to use a *china marking pencil,* and that such marks should not extend over two frames.

The inspector should examine the marginal footage numbers on both sides of each splice when inspecting sound film, so as to determine the probable deletion of footage. If the deletion is large or important, replacement film is necessary. Companies that do not adhere to a distinctive uniform splice should require that each splice made and examined be stamped with an embossing stamp to signify that the footage deleted has been "okayed." This precludes the necessity of a like examination in following inspections.

The inspection should be supervised by a person well informed in the work, who should always be in close contact with the booking department, and be responsible to it for the correct maintenance of

the film. Care should be exercised by the personnel department as to the ability of persons employed to inspect film.

Various forms are necessary in every inspection department: (*a*) an individual notebook, maintained by each inspector, showing the amount of work done daily, the production number or title of each subject inspected, and the number of reels and their condition. The supervisor should determine from these notebooks the amount of work done each day, and should render to the branch manager a weekly report showing a complete résumé of the work; (*b*) forms for reporting damaged film to the booking department, to be filled out by the inspector's supervisor; (*c*) forms for ordering replacement parts, to be filled out by the inspector's supervisor, and handed to the booking department.

(*2*) *Storing of Film.*—Film should be stored only in sprinkler-equipped vaults or cabinets properly vented, and built in accordance with the code of the National Board of Fire Underwriters, and all local fire ordinances.

Film that is yet in its booking stage should be filed in film vaults in the I. C. C. container in which it is shipped to the theater. Film to be stored permanently should be removed from its reels and filed in individual approved containers. The sub-committee recommends that the temperature inside the vaults be kept as nearly at the temperature of the shipping room as is possible in exchanges through which film is passing. For storing and preserving film permanently, the temperature of the air should be maintained approximately at 65°F. to 70°F. at a relative humidity of 65 per cent.

(*3*) *Shipping Routines and Records.*—The shipping and receiving of film and the routine used in these connections can more easily be standardized than the inspection and maintenance of film, for the reason that no variations occur in the shipping routines found in different localities or in small or large exchanges. All movements of film are recorded on the "film record card." No film of any footage whatsoever, except scrap film, should be sent from the film room without an order from the person or department authorized to make such orders directing its movement. Scrap film should be delivered only to a person or agency duly authorized by the city authorities to collect it, and, regardless of quantity, should never be burned in the basement of the building or in any adjacent lots.

The forms used in shipping and receiving film should include a daily shipping sheet, made up by the booking department and ac-

companied by individual shipping orders from the accounting department, shipping labels, caution labels, C.O.D. labels and orders for shipments to be sent C.O.D., express delivery records, receiving records, reports for overdue film, and packing slips for return of "junk" film.

(4) *Housekeeping and Control of Fire Hazards.*—Conditions and control of fire hazards in both inspection and shipping rooms, and in the vaults of an exchange, should be standardized as far as possible. The sub-committee recommends that the rules governing these conditions, as laid down by the National Board of Fire Underwriters and supported throughout and followed up by the Department of Conservation of the Motion Picture Producers and Distributors of America, be endorsed by the S. M. P. E. and recommended as standards of procedure for all exchanges of all companies. The Department of Conservation of the M. P. P. D. A. has been following this work completely and thoroughly, as evidenced by the almost total elimination of losses by fire in exchanges that are receiving the benefits of systematic inspection by that organization.

No unauthorized visitors should be permitted in the film rooms of an exchange. Delivery boys, projectionists, and messengers picking up film, should not be allowed free access to the film rooms.

(5) *Equipment.*—All equipment used in maintaining film and in shipping and storing it should be standardized for all exchanges as far as possible, so that a uniform procedure may be followed. Requisite equipment of film inspection rooms consists of tables, chairs, rewinds, mounting flanges, splicing blocks, title cabinet, leader cabinets, waste film containers, trash cans, cement bottles and spreaders, film band holders, supervisors' desks, and filing cabinets.

The use of automatic splicing machines equipped with table tops obviates the need of separate tables. Such machines are desirable because of the greater ease and satisfaction that results from using them and the greater volume of work that can be accomplished with them. Where manually operated splicing blocks are used, all-metal inspection tables and adjustable, form-fitting chairs are recommended.

A standardized rewind for all exchanges is recommended. It is desirable that all rewinds be equipped with brakes, controlled by the knee of the operator or by the handle of the right-hand rewind, arranged so as to stop both rewinds simultaneously when applied.

Mounting flanges should be of standard uniform size so that the

hole in the center of the unmounted reel will always fit the hub of the flanges.

A desirable title cabinet is one built on the order of a chest of drawers. Each drawer should be approximately two inches deep, studded with upright movable pegs on which to insert the titles and their corresponding tags. This cabinet should be kept in one of the film vaults.

Leader cabinets should have three compartments for the three different kinds of leader required for the maintenance of film footage. The gates or apertures through which the film leader is drawn as needed should be so built as to prevent fire from passing into the cabinet. Film band holders may be of any type of wall bracket.

Waste film containers should conform to the code of the National Board of Fire Underwriters.

Cement bottles should hold no more cement than the amount required for one day's work, and should be equipped with a metal spreader built into a metal stopper, the weight of which keeps the bottle closed.

The supervisor's desk should be made entirely of metal and should have sufficient drawer capacity for keeping all records when not in use. Filing cabinets should be made entirely of metal and should have sufficient capacity for filing continuity sheets, records, *etc.*

The equipment of the film shipping room should consist of packing and receiving tables, hand trucks, chairs, waste film containers, tools, shelves, shipper's desk, filing cabinets, and trash cans.

Packing and receiving tables should be strong and made entirely of metal. They should not be higher than 30 inches. The shelves should be sufficiently strong and made entirely of metal, and should have sufficient capacity for storing all cases of film awaiting shipment or inspection. Hand trucks should be made entirely of metal and should be equipped with rubber tires. The shipper's desk and chair should be made entirely of metal, the former having sufficient drawer capacity for keeping all records when not in use. Filing cabinets should be made entirely of metal and should have sufficient capacity for maintaining a complete file of film record cards, showing the "in and out" movement of film, and for filing all shipping and receiving records. Waste film containers should conform to the code of the National Board of Fire Underwriters, and should be kept in one of the vaults. Trash cans should be of the usual type, having tightly fitting lids or covers. Tools of sufficient variety to enable

the shipper to repair equipment and cases properly should be available.

(6) *Home Office Control.*—The practice followed by the film exchanges should be controlled by the home offices, and should be made to conform to the procedure adopted by them. The exchange manager should see that the routine standardized by the home office is rigidly followed in his exchange by, first: the adoption of the best routines for the maintenance of film and reporting to the home offices all particular conditions pertinent to them; and, second, the thorough and capable following up of the procedure by the home office, so that the national routine may be emended or altered when better methods of operation are developed by an individual exchange.

Exchanges should render weekly reports on film inspection. When reports are compiled, a national summary is obtained, from which each exchange may be judged as to the volume of work, cost of inspection, shipments, and amount of uninspected film in the vaults. Exchanges should also report all fire hazards at least once a month, supplementing the monthly report made by the Motion Picture Producers and Distributors of America. Traveling auditors from the home office also should include in the audit of each exchange an accurate and complete description of all fire hazards.

The home office should have available a representative who is thoroughly informed in film maintenance so that his services might be furnished to an exchange when needed. The control by the exchanges of the care of film while in the hands of the projectionist should include only a correct record of the condition of the print furnished to the theater and an observation of its condition on its return. Such records assist in avoiding controversies over damaged film and charges rendered to the theater by the exchange.

The success of the film exchange in its work depends upon furnishing the exchange with the correct equipment, establishing uniform standards of routine in all exchanges, and control by the home office to see that the adopted routine is carried out.

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# FILM RECORDERS*

A. G. ZIMMERMAN**

**Summary.**—*The evolution of the modern high fidelity recorder, from the relatively crude apparatus first used for recording when sound was added to the picture, is traced; beginning with the telegraphic recording device known as the pallophotophone developed by C. A. Hoxie, passing through the phonofilm devised by L. de Forest, and continuing through the RCA PR-1 and PR-3 to the up-to-date PR-4 variable width recorder embodying the latest developments for maintaining a high constancy of speed and for producing recordings of the highest quality. The paper describes the new model recorder and film phonograph, and the application of these to dubbing and re-recording, both on 35-mm. and 16-mm. film.*

From the time that Thomas Edison made the first scratch in the foil-covered cylinder down to the present day, the words *quality* or *fidelity* have been used in criticism of the recordings that were made, no matter what method was used. These words define, perhaps, a condition of pleasantly or satisfactorily exciting the auditory nerves in a manner bearing a recognizable relation to the original sound. It is highly probable that with Mr. Edison's first recording, the tremendous impetus that he received from having accomplished what was heretofore locked in the fastness of the unknown, caused him to rejoice in the discovery that he had made. It is a historic fact that Mr. Edison and his co-workers gave some thought at that time to one feature of recording that in this day and age has become of paramount importance. This feature was partially obscured by the fact that he had "re-created," in the form of a permanent or semi-permanent record, an audible sound that once had been, and could be no more.

As the art of recording progressed, all the individuals connected with it came to realize that the attainment of good *quality*, as regards the frequency composition of sound, was one of the greatest problems confronting them. But quality was found to have a wider scope, and to include a definite relation between the frequency characteristic and the constancy of speed maintained while recording and reproduc-

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ing the sound. As in all developments of this nature, the past efforts, when reviewed at some later time, were considered to be poor replicas of what had been recorded, and served to emphasize the achievements accomplished during the interim.

The progression from the cylinder to the disk type of record brought with it considerable advantages, both from the commercial and from the technical standpoint, when the increase in the linear speed was considered as well as the creation of a more flexible product. This advance brought with it a wider field for the sale of records and reproducing machines or phonographs.

Departing from the field of quality with respect to the frequency standpoint and considering only the question of constancy of speed,* it is very probable that since the conception of the phonograph down to the present day, millions of dollars have been spent by firms engaged in the original recording of phonograph records for sale, by others engaged in marketing reproducing machines, by engineers, and other individuals too numerous to mention who were privately interested in solving the problem of speed constancy. Undeniable strides were made in reducing, to a tolerable limit, the variation of speed that occurs in recording and reproducing equipment of the phonograph type.

Mr. C. A. Hoxie, of the General Electric Company, conceived the idea of a telegraphic recording device that would enable a telegraph company to receive telegraphic communications at high speed on a continuous paper film and to preserve them for their records.** As soon as this device had been created and so improved as to be able to record messages at speeds previously considered impossible, the ever alert engineering instincts of the men responsible for this de-

* Inconstancy of speed results in variations usually termed *wows* when they have a frequency below 10 cycles per second; *flutter* up to 50 cycles, and *gurgle* above 50 cycles. The frequency of the *gurgle* is usually dependent upon the number of sprocket teeth engaging the film.

** A historical point worthy of mention is the fact that the original sensitized paper film recorder was developed to record the telegraphic signals when transmitted at the usual maximum speed of 25 to 35 words per minute. Concurrently with the development of the recorder, the possibility of increasing the speed was apparent, and during the winter of 1918 and 1919 a Hoxie telegraphic recorder was operated at Otter Cliffs, Bar Harbor, Maine, handling traffic from Lyons, France, at an average speed of 50 words per minute. Further developments and tests demonstrated the ability of this type of equipment to receive as many as 250 words per minute.

velopment conceived the idea that not only telegraphic messages, requiring only the comparatively simple dot-dash method of recording, but other sounds, such as the human voice and music, could be recorded on a piece of film, which could be processed and reproduced.

In 1922, Mr. Hoxie developed what is now known to the industry as the *pallophotophone*,* which he described in detail at the Mid-Winter Convention of the A.I.E.E. in New York in 1923.

The success of Mr. Hoxie's trials and demonstrations of the pallophotophone immediately created an impression on the minds of interested persons that the era of talking pictures was definitely at hand. Dr. Lee de Forest's demonstration of the *phonofilm* at approximately the same time also contributed to the advent of the "talking picture." It is not to be inferred that these two men were the first to think of "talking pictures" with the sound recorded on the film, but credit is due them for their efforts in accomplishing and presenting for commercial development what had heretofore been accomplished only in the laboratory or had been conceived but never accomplished.

The pallophotophone and its uses and demonstrations aroused attention to a requirement that had been of considerable importance to the record industry previously to this time; namely, the constancy of speed that should be maintained in recording as well as in reproducing sound on film.

It was found that when recording sound on a continuous strip of film, particularly the recording and reproducing of sustained notes, the least possible variation of speed of the film was required as it moved past the recording or the reproducing light. These variations would produce objectionable variations in the reproduced sound and prevent it from being a faithful replica of the original sound. It was apparent, then, that with the advent of the talking picture, suitable equipment for recording sound on film and for reproducing the sound from the film would be required. Mr. Hoxie and some of his associates designed and built a film recorder known at the time as the *kinegraphone*, later known as the *photophone* film recorder. This device, designated the *PR-1 Recorder*, employed a

* The name *pallophotophone* has been given to devices used for permanently recording speech as a wavy trace on a moving photographic film, and for transforming the air vibrations of sound directly into exactly corresponding electrical vibrations for transmission; for example, to wireless broadcasting generators. The word is a Greek derivative, signifying "dancing light."

synchronous motor and a train of gears driving two sprockets. As the film passed through the recorder, it was drawn over a cylindrical drum, to which a flywheel was attached by means of a shaft. This drum was isolated from the sprockets, and the sprocket-tooth pulsations, by means of loops of film threaded around suitable rollers, although the film was relied upon to drive the drum. Acoustical power recording methods could no longer be used; the method of recording on the film, in the *PR-1* recorder, was an outgrowth of Hoxie's work with the telegraphic recorder and other work done in the laboratories of the General Electric Company on oscillographs and vibrators. In the field, the *PR-1* recorder performed remarkably well, notwithstanding the obstacles with which it had to cope. It was the first commercial film recorder to be called upon to withstand the rebuffs of a slightly unsympathetic film industry, to say nothing of some rather belligerent directors and directors' staffs. A new era had dawned in the film world, and the *PR-1* took its place in the front ranks of the invaders.

Recollections are not all that remain of the hectic days during the nascency of "sound" and its adoption by the already mature and undoubtedly independent silent film industry. Much was to be learned from the conditions prevailing in the studios under which the sound equipment would have to work. Where laboratory experiments had sufficed for the original developments, field experience was now to be had; and in so far as the recorder was concerned, commercial film presented problems, both chemical and mechanical. Only the mechanical difficulty of shrinkage and its relation to the attainment of constant speed will be discussed. In the *PR-1* recorder, the isolating loops between the sprocket and the film drum were of such a nature that when a disturbance occurred in the speed of the film during recording, more filtering or damping action was required than the flywheel alone would furnish. This resulted in an unsteady motion of the film past the recording light beam.

A new recorder, the *PR-3*, was developed, in which was employed a mechanical device to compensate for the shrinkage of the film. In the *PR-3*, a synchronous motor was used to drive a flywheel through a pinion and gear, or a worm gear reduction. On the same shaft with the flywheel, within the recorder head, a sprocket was mounted, which pulled the film from the film magazine. A cone on this shaft was arranged to drive another cone on the recording drum shaft through the medium of an idler, the position of which was

determined and controlled by means of a compensating roller in the film path within the recorder head. This mechanism would compensate for shrinkage of the film, causing the speed of the recording drum to be in accordance with the exact linear dimension of the film. This compensating mechanism, although a mechanical device, served to make sound-film very superior to that obtainable with the now obsolete *PR-1* recorder.

As was to be expected, the device employing the mechanical means

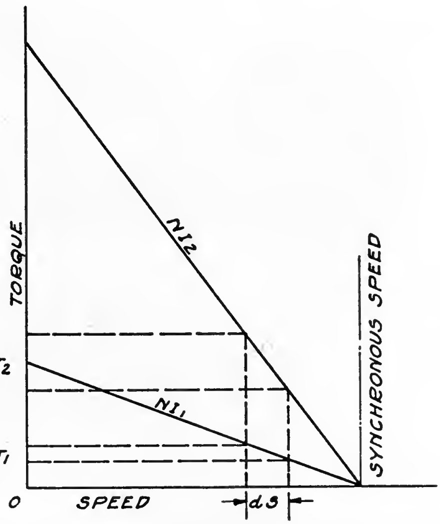


FIG. 1. Speed-torque curve of the electromagnetic drive of the PR recorder.

of maintaining a constant film speed in the *PR-3* recorder was not free from mechanical troubles, starting with the friction between the cone and the idler of the compensating mechanism. Mr. E. W. Kellogg, of the General Electric Research Laboratories, realizing the difficulties of the mechanical compensating device, and aware of the advantages to be gained by isolating the film drum from the remainder of the operating mechanism, developed in the laboratory a recorder that employed a magnetically overdriven drum.[1] The advantages of this construction were immediately apparent, and a new type of recorder was designed and built, in which were incorporated all the advantages of the earlier recorders as well as the improvements necessary to overcome the disadvantages or troubles encountered in

manufacturing them and operating them in the field. This recorder was known to the industry as the *PR-4*. With this instrument it was feasible to record on film the sustained notes of the piano, without being able to detect any variation of frequency when the sounds recorded on the film were reproduced. Having accomplished this objective of maintaining a sufficiently constant speed of the film, it then became necessary to combine the new features that enabled this to be

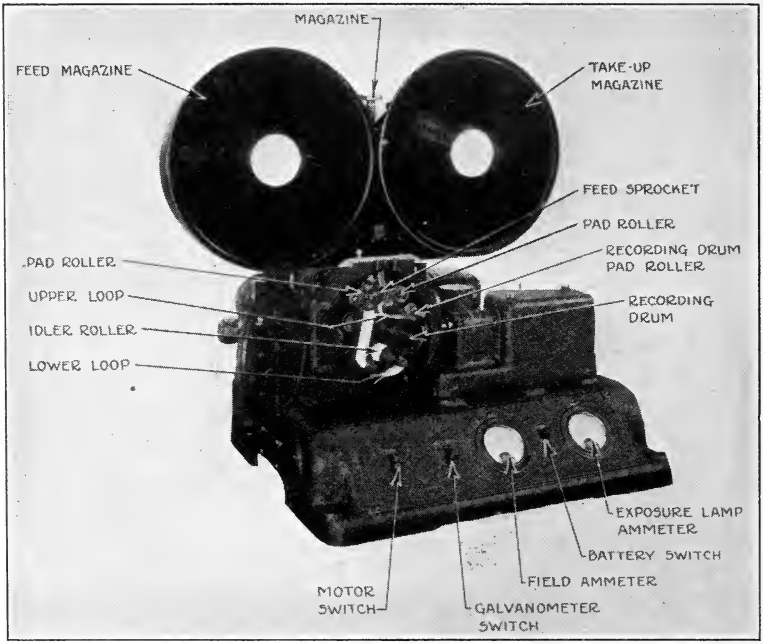


FIG. 2. Front view of a model 4PR18A1 35-mm. film recorder showing threading.

done with other features that were the outgrowth of extensive field experience.

With the development and manufacture of the *PR-4* recorder, the limitations and other objectionable features of the oscillographic type of galvanometer were vacated by using a galvanometer of such design that the moving parts were more readily controllable and the frequency range extended beyond what was reasonably and economically possible with the oscillographic type of vibrator. After a recorder

embodying this new vibrator had been placed in service in the field, the advantages of reducing the ground noise of the film record, during passages of small amplitude or during quiet intervals, became apparent. This consideration led to the development of equipment comprising an amplifier arranged to operate a shutter vane, which intercepted part of the beam of the recording lamp, so that, when the amplitude of the sound that was being recorded exceeded a certain threshold level, the full output of the amplifier would be available. This arrangement improved the quality of the record considerably,

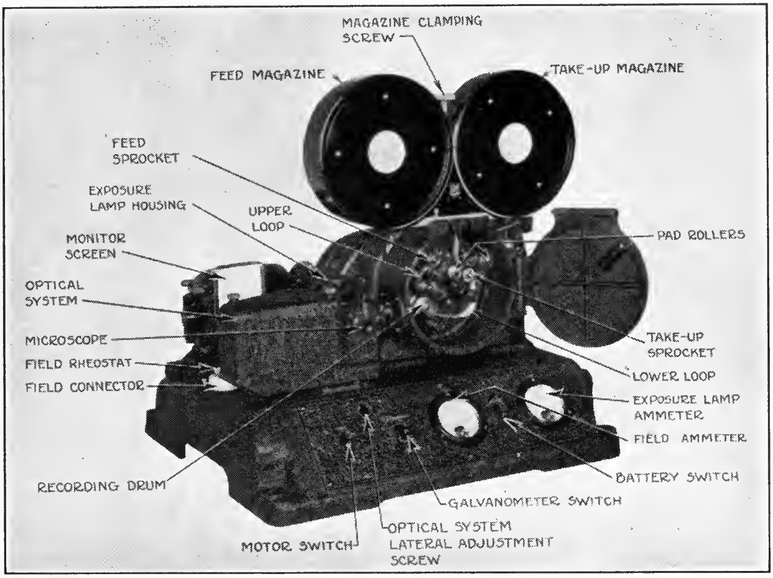


FIG. 3. Front view of type PR-19 16-mm. film recorder showing threading.

as, by means of it, shots taken without speech or music would be almost completely "blacked out" on the positive film and neither scratches nor dust would cause disturbances in the reproduced sound.

By the time the *PR-4* recorder was operating in the field, the public had whole-heartedly accepted the talking picture, so that in that respect the metamorphosis of the silent picture was complete. Directors and associates, including the actors, had come to realize that the technic of recording sounds on film had changed the old order of

affairs to such an extent that, with complete coöperation, the art was considerably advanced.

In order to keep pace with the rapid advances made in the laboratories and in the field, where literally thousands of technical men were developing new equipment or operating the old equipment (on a commercial basis), it was necessary to provide the film industry with new and improved tools. Consider by what yardstick the new recorders were to be measured: primarily, as has been shown, the recorder

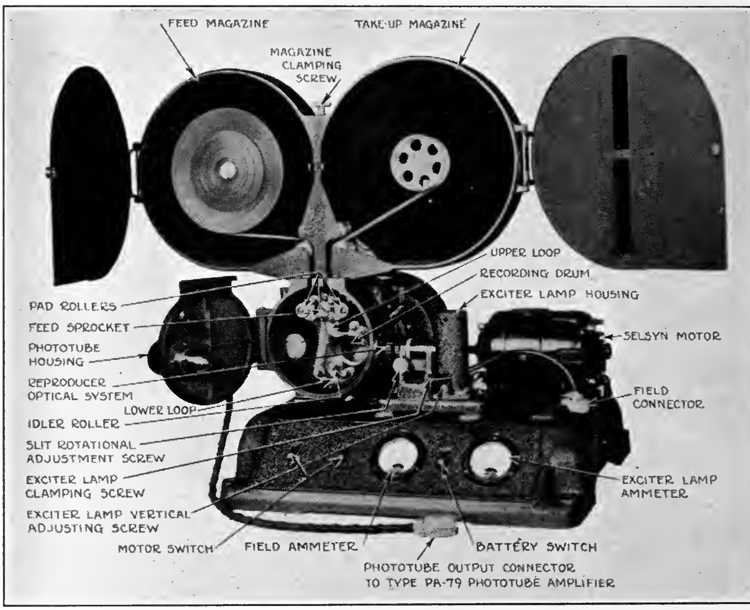


FIG. 4. Front view of a model 4PB36A1 35-mm. film phonograph.

would be required to record sound on film with the utmost attainable as regards constancy of speed and range of frequency. The recorder would have to embody, as well, the attributes of ruggedness, simplicity, flexibility, and durability. *High fidelity* was, then, to be realized, at least as far as recording was concerned, in the latest film recorder available to the film world—the *PR-18*.

From the point of view of the recorder, we find *high fidelity* requiring two important features, as before: constancy of speed and

adequate range of frequency. In so far as the speed was concerned, with the electromagnestically driven recorder drum as used in the *PR-4*, constant frequency recordings of continuous frequencies were assured, without perceptible variations of speed. (It is to be noted that in making measurements of this kind, the methods used are rather simple but the work becomes quite fine and would warrant a detailed description not possible at this time.) A sleeve-bearing formed the journal for the sound-drum shaft, so it was necessary to

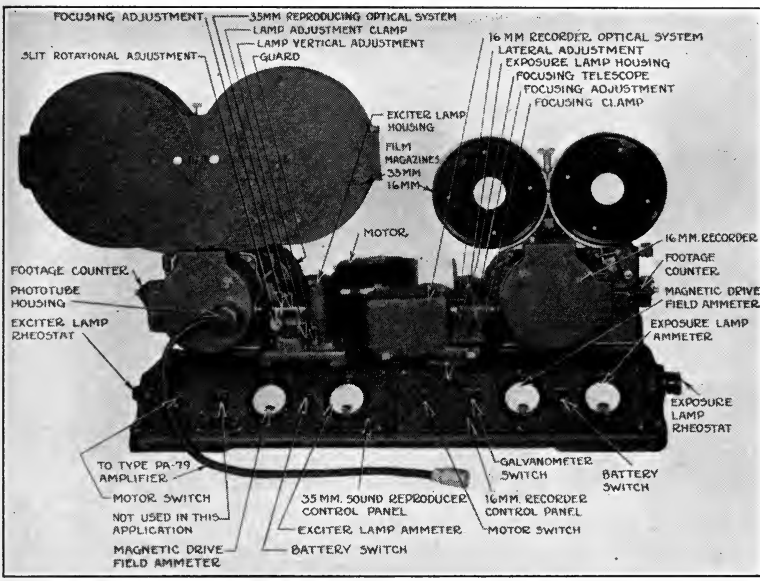


FIG. 5. Front view of type PB-38 35-mm. to 16-mm. film re-recorder showing threading.

develop a combination of bearing and shaft metals and a lubricant that would insure minimum friction, minimum bearing noise (mechanical), and maximum uninterrupted service. The shaft and sound-drum of the recorder were made of stainless steel so as to avoid corrosion. Considerable developmental work had to be done before the proper combinations were determined and acceptably proved.

From the electrical point of view, although the magnetic drive has been explained previously,[1] a brief description of it may be in order at this point. It consists of a solid copper annulus, fixed in a support-

ing flywheel attached to the drum-shaft. An electromagnet, driven by the recorder motor through reduction gears, is constructed so that an annular air-gap is formed on its rear surface. The copper ring, by reason of its construction, fits into the air-gap and rotates only when the electromagnet is properly excited by a direct-current source.

Fig. 1 shows a speed-torque curve of the magnetic drive motor. In this curve, $NI_1$ represents the field excitation for a given current; and $NI_2$ the excitation for a greater current, producing a proportionately greater flux density in the air-gap. From this figure, it is evi-

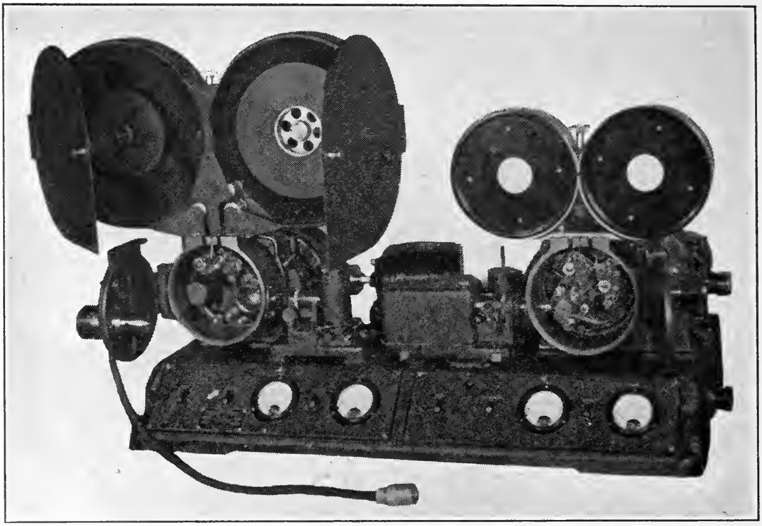

FIG. 6. Front view of a 4PB38A1 35-mm. to 16-mm. re-recorder showing threading.

dent that for small changes of speed ($dS$) of the film drum (no matter what the cause), there will be an opposing or damping action measured as an increment of torque in accordance with the subtended lines shown on the vertical scale. It is further evident that the greater the slope of the curve, the greater will be the damping produced by the increment of torque $dT$. The magnet drive in the recorder is usually designed to drive the magnets at a speed that is approximately 10 per cent greater than the speed of the drum.

An optical system[2] capable of responding faithfully to the increased frequency range, and yet simple and rugged enough to be a

practical "tool," had to be designed. The optical parts in general were mounted on a unit casting and designed so as to prevent all possible variations in their arrangement. The galvanometer was of a new type, necessitated by the extension of the range of frequency of the response. It is of the balanced armature type, and employs a mirror of such dimensions that the "edge to area" ratio is reduced to a harmless minimum, resulting in a substantial reduction of the stray light impinging on the film. The stray light is reduced still further by mounting the window in front of the mirror at an angle, so that any secondary reflection from it will not impinge upon the mechanical slit. The reduction of the stray light and the increase in the area of the mirror permit the use of a less sensitive film for a given current in the exposure lamp.

The operation of the optical system differs from that of all previous types in that the sound track is recorded by moving a triangular light image in a vertical direction across a horizontal slit, and optically reducing the cross-section of the light beam so that the sound track becomes a serrated pattern on the film, varying from a 0.002-inch line at the center to the full width of the sound track, on both sides of the center. The resulting sound negative then becomes two identical serrated transparent areas, completely separated by an opaque area. One description given of the sound track is that it resembles "a mountain chain and its reflection, as mirrored in a body of water at the foot of a range."

In this optical system, the ground noise is reduced by depressing the light image (by direct current supplied by the ground noise reduction amplifier) to such an extent that the tip of the triangular light image is just incident upon the mechanical slit. This produces on the film an opaque track 0.002 inch wide. By means of a bias winding in the galvanometer, in addition to the modulation winding, and by using the ground noise reduction amplifier, this depressing action is made to occur when no modulation is present in the recording channel. As soon as modulation occurs, or a modulating signal is picked up by the microphone, the ground noise reduction amplifier, by means of a timed circuit, operates and permits the modulation coil of the galvanometer to vibrate the mirror in accordance with the incoming alternating-current signal. The mechanical construction of the galvanometer is extremely simple, and, due to the fact that the armature is designed so as to become saturated at a predetermined flux density, the galvanometer is practically self-protecting.

A volume level indicator or "monitor" is mounted on the top rear surface of the base casting. It consists primarily of a small paper screen upon which a small portion of the vibrating light beam is focused. This small portion of the beam is reflected to the screen, through a window in the cover, by a mirror that intercepts an independent beam of light parallel to the recording beam. By drawing lines on the card and by observing the relative position of the light beam while recording, it is possible to observe very accurately the modulation of the sound track.

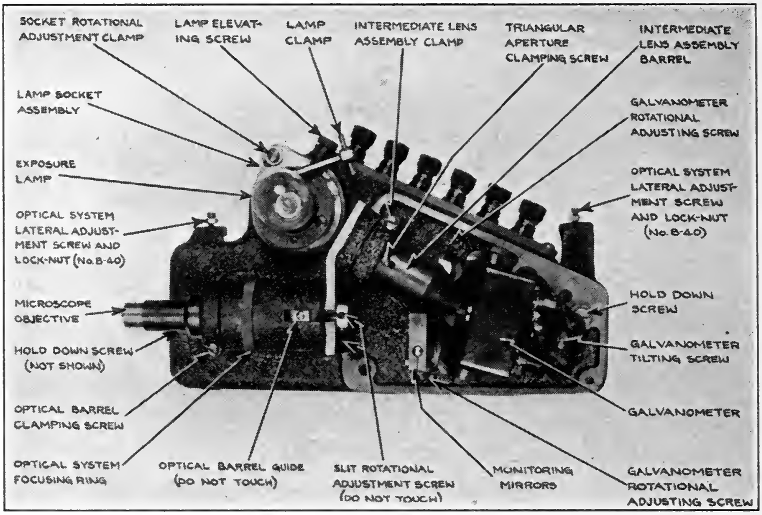


FIG. 7. . Optical system used in type PR-18 film recorders. Top view with cover removed.

Having the elements of a successful recorder, namely, the constant-speed film drive and the optical system, it was then necessary to insure mechanical reliability by mounting all the equipment on a rugged base. This base was designed to house and protect all the apparatus incident to the recorder itself, such as the galvanometer transformer, the lamp control rheostat, and the field rheostat. Connections were made to the audio and power circuits of the recorder by means of *Twist-Loc* receptacles mounted in panels on the rear of the base. This method of connection avoids permanent wiring of the installation. Provision was then made for a control panel, whereon the lamp

and field ammeters, the galvanometer, motor, and the battery switches were mounted.

Thirty-five-mm. recorders of the *PR-18* type have been in constant service for the past seven or eight months, and sound records are being commercially produced with them of an excellence that heretofore has been sought after, but never attained.

Having produced such a recorder, embodying all the mechanical

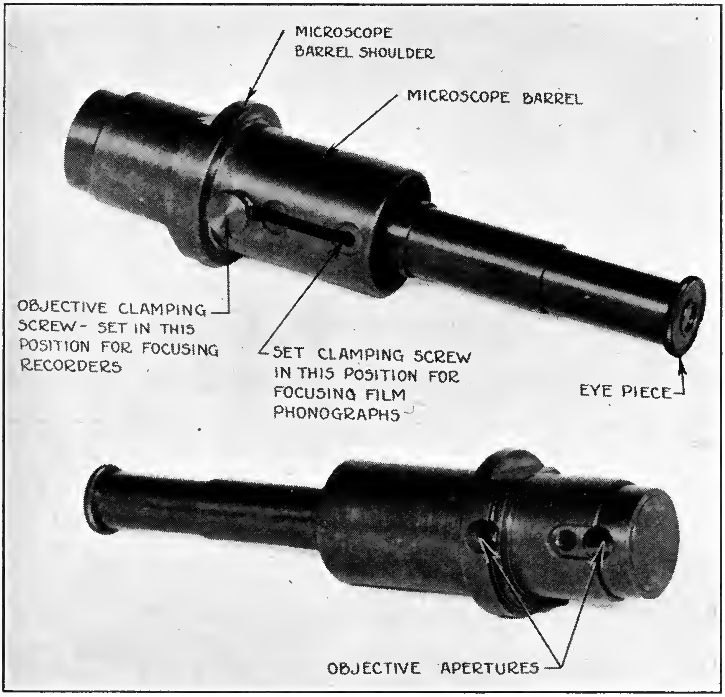


FIG. 8. Focusing microscope for use with 35-mm. film recorders and film phonographs.

features that have been mentioned, and having available all of the attributes necessary to record sound on film at a constant speed, it was immediately evident that these features could be incorporated into an equipment capable of reproducing sound with the same nicety. In order to accomplish this, it was necessary to replace the optical system of the recorder with a system designed to reproduce the high fidelity records made with the recorder. Here again, the

requirements of the field demanded that such a system be provided as would reproduce sound tracks faithfully no matter what type of record was used or to what extent the recordist had misplaced the sound track or misaligned the recording slit. The optical system that was developed includes a high-intensity filament lamp and a mechanical slit 0.0025 inch wide, the latter being optically reduced to a slit dimension at the film of 0.0005 inch. The optical system is arranged so that it can be adjusted to the point of critical focus by means of the focusing microscope. An important feature of the system is the arrangement by which the entire optical barrel is positively rotated $\pm 2.5$ degrees in steps of 0.1 degree. This feature enables the operator to reproduce sound tracks that have been made either in haste or when insufficient care was taken in aligning the optical system

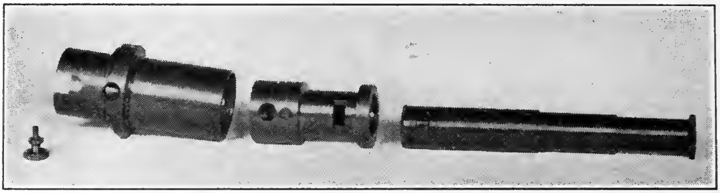

FIG. 9. Focusing microscope—component parts.

slit of the recorder. This device has found considerable favor in the field due to the facility it provides for making the optical adjustments. In speaking of the focusing microscope, the question may arise as to how it is possible to design a device of this type that can be made readily available for use in a recorder as well as in a film phonograph. Fig. 8 shows the assembly of the focusing microscope; Fig. 9 shows the component parts, indicating the stop adjustment, which is set by the operator for the machine with which he is using the instrument.

With the film phonograph shown in Fig. 4, it can be seen that film in rolls (kept in this manner to prevent reel marks) can be readily inserted into the new type of magazine and threaded through the recorder head up into the take-up side of the magazine. The reproducing optical system is arranged so that the light passes through the film to a photocell mounted in the door of the film phonograph. This is connected by means of a cable to the phototube amplifier. The output of this amplifier matches the input of the microphone distribu-

tion panel of the standard recording channel. From here, the sound may be mixed with the output of separate microphones or with the output of other film phonographs in order to create various sound effects on the final films.

With a processed film reproduced by the film phonograph, it is possible to combine two or more sound tracks, to add sound effects to an original recording, or to match sound levels in the finally edited picture. The user of the equipment is then enabled to make high quality re-recordings and dubbings with complete confidence.

Film phonographs are usually furnished with a Selsyn motor mounted on the base. They are used mostly in re-recording channels, where the projectors and recorders are operated from a master Selsyn motor-generator set. The film phonograph is provided with a synchronous motor drive for recording incidental sound effects or for reproducing "takes" independently in order to check the quality of recording that has been obtained.

A distinct advantage of the film phonograph as thus designed is that fresh or "green" film, or rushes, may be run through the machine without danger of damaging the emulsion by pulling the film through a sound gate and shoe, because during the course of the film through the film phonograph head it comes into contact with the surface of only one roller immediately before it enters upon the sound drum.

This device, like the recorder, is equipped to accept all power and sound circuits in suitable *Twist-Loc* connectors mounted on panels on the rear of the film phonograph base. Also, as in the recorder, the controls are mounted on a sloping panel directly in front of the operator. The exciter lamp rheostat is located on the left-hand side of the base casting within easy reach.

Due to the demand for a recorder capable of recording sound on 16-mm. safety stock with a constancy of speed comparable with that obtained with nitrate stock at 90 feet per minute, it was evident that the electromagnetic drive could be applied to such a recorder. With the idea in mind that the greatest number of recordings on 16-mm. film would be made by direct re-recording, the recorder was built as the reverse of the 35-mm. film phonograph. This was done so that both machines could be mounted on a single base, to be driven by one motor and the controls and necessary optical systems brought within easy reach and observation of the operator. The 16-mm. recorder, although operating at only 36 feet per minute and handling safety stock with its inherent difficulties, embodies the same features

that are found in the 35-mm. recorder; and in so far as constancy of speed is concerned, it has not been excelled.

In the development of the 16-mm. recorder, and in order to utilize the advantages of the magnetic drive, the size of the recording drum had to be such that it was impossible to use a device similar to the focusing microscope as used in the recorder and the film phonograph. A microscope was therefore mounted in the side of the lens barrel of the optical system; arranged so that it could be used to observe the emulsion on the film through the objective lens of the optical system, and obtain thereby extremely accurate adjustment. The optical system includes essentially the same components, and the same arrangement of these components, as a 35-mm. recording optical system; and monitoring is accomplished in the same manner as in 35-mm. recording, by observing the monitoring light beam as focused on the monitor screen mounted on the rear of the casting.

Having available the high-quality film phonograph and the 16-mm. recorder, it was thought advisable to make available, for those interested in the development of the 16-mm. sound library, a re-recorder capable of either (*a*) re-recording from a 35-mm. sound print to a 16-mm. film; (*b*) reproducing 35-mm. sound film for listening or dubbing work; or (*c*) recording directly on 16-mm. film. It was not thought economical to make the original recordings on 16-mm. film, due to the fact that the cost of cutting and editing this film, compared with that of making direct re-recordings from existing 35-mm. libraries, would be excessive.

The sprockets of the reproducer and the recorder are driven through reduction gears by a single synchronous motor, thus insuring the synchronization of the master 35-mm. print with the 16-mm. print, so that when the picture is printed on the 16-mm. film no difficulties will be encountered in synchronizing them. The recorder also includes the feature of housing all the equipment requisite to the reproducing and recording mechanisms. Controls for the exciter lamp and the exposure lamp are mounted on either side of the casting near the front. The motor switch is made common to both the reproducer and the recorder panels, so that the machine may be operated from either point or the two units may be operated individually. The reproducer panel contains the battery switch, the field ammeter, and the exciter lamp ammeter. The recorder control panel contains a galvanometer switch, the field ammeter, the battery ammeter, and the exposure lamp ammeter. All external power and sound circuit

connections are made through the standard *Twist-Loc* terminals inserted in panels at the rear of the base casting.

Briefly, then, the 35-mm. film recorder has progressed from a comparatively crude device and utilizing an acoustical method of modulating the recording light beam into a highly perfected machine in which is employed a drive that is almost perfect. The equipment includes an optical system approximately half as large as the earlier system and of a comparatively simple design. The recording is no longer done acoustically, but an improved optical system and a galvanometer of rugged construction are used, capable of recording faithfully a frequency range from 50 cycles to 10,000 cycles. The entire equipment has been mounted on a base so designed that permanent wiring and mounting are unnecessary, and all the controls are within the operator's reach.

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# THE RELATION BETWEEN DIFFUSE AND SPECULAR DENSITY*


CLIFTON TUTTLE**



***Summary.***—*After briefly referring to the effect of the scattering of light upon measurements of density, according to the way in which density is measured, the author alludes to various attempts made in the past to find a quantitative relation between the specular density and the diffuse density of a medium. A special projection densitometer was designed for measuring the specular density, and a form of integrating densitometer for the diffuse density, of a number of samples of negative and positive motion picture film. The results indicate an exponential relation between the two kinds of density, the time of development and the variation of gamma, within the range of the measurements, being negligible.*


The influence of the scattering of light by the developed silver grain upon the effective optical density of a photographic deposit is of considerable importance to both practical and scientific users of photographic materials. Density, which is defined as the common logarithm of the ratio of incident flux to transmitted flux, instead of being a definite property of the silver image, is dependent upon the characteristics of the optical system of which it is a part. If the measuring instrument is so placed as to record only the flux transmitted in a direction normal to the plane of a light-scattering medium, the density value will be greater than for the case where the measurement is based upon the total transmitted flux. The first case, which has been termed specular density ($d\|$), is the value that is of interest in dealing with images for projection—lantern slides, motion picture positives, and negatives for enlargement. The second case, which is usually spoken of as diffuse density ($d\#$), is of interest in contact printing, where the negative and the positive materials are in juxtaposition and the total transmitted radiation is effective.

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* Communication No. 258 from the Research Laboratory of the Eastman Kodak Company. Originally published in *J. Opt. Soc. Amer.*, **XII** (June, 1926), pp. 559–565. In a subsequent paper by Silberstein and Tuttle, *J. Opt. Soc. Amer.*, **XIV** (May, 1927), pp. 365–373, a formula correlating the two densities was derived from general theoretical considerations.



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The dependence of the density values upon the manner of making the measurement was the subject of an extended controversy between Hurter and Driffield and Abney.[1] Abney pointed out the effect due to light scattering. Hurter and Driffield agreed with the

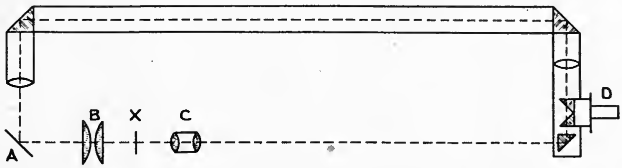


FIG. 1. Projection densitometer: $A$, 900-watt monoplane filament lamp; $B$, 5-inch condensing lens; $X$, photographic material; $C$, $4^1/_2$-inch projection lens; $D$, Martens polarization photometer.

criticism offered by Abney, but stated erroneously that the scattering interferes only in plates of very high densities. Callier, in his well known paper on the scattering of light by photographic materials,[2] investigated a number of photographic emulsions, and concluded that the relation between diffuse and specular density was approximately satisfied by the equation $d_{||} = Qd_{\#}$, where the factor

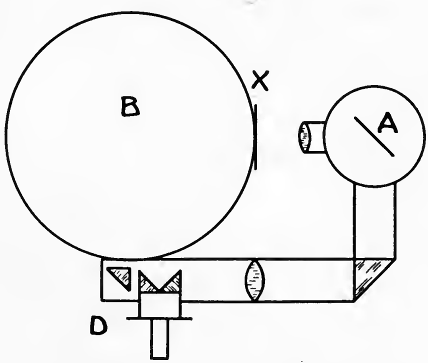


FIG. 2. Integrating densitometer: $A$, 250-watt monoplane filament lamp; $B$, 12-inch integrating sphere; $X$, photographic material; $D$, Martens polarization photometer.

$Q$ is a constant for a limited range of densities. Callier's measurements of diffuse density were made with the photographic material in contact with opal glass, which was assumed to be perfectly diffusing. Under such conditions, the values he obtained would be true

diffuse density values within the range of the densities measured, since here the effect of interreflection is negligible.

Renwick and Bloch[3] have shown that an equation of the exponential type fits Callier's data with greater accuracy than the linear function given by Callier.

It has been questioned whether diffuse density measurements give the true contact printing density. Toy[4] found that diffuse density, when measured by the use of an opal diffuser, must be multiplied by a constant factor to give the true printing density. Bull and Cartwright,[5] however, found that an integrating-sphere densitometer gave true contact printing density readings.

The photographic literature is replete with discussions of methods and instruments for measuring density and with treatments of the theoretical and practical aspect of the scattering of light by turbid media. A detailed review and analysis of these papers is beyond the scope of the present work. Those engaged in photographic research are probably aware of the uncertainties arising from the use of different instruments employing light sources with varying degrees of collimation. On the other hand, many scientists who make constant use of the photographic plate as a measuring instrument appear to be quite unaware of its limitations in this respect. The magnitude of the difference between diffuse and specular readings in the data of the following investigation serve to emphasize the necessity for careful consideration of this property of photographic materials.

It is highly desirable at times to express one density in terms of the other, *i. e.*, to evaluate contact printing density from measurements of projection density and *vice versa.* Such a case arose in connection with some work on tone reproduction in motion pictures, in which it was desired to trace the reproduction of original object contrast through the steps of printing the negative by contact and projecting the positive on a screen. The measurement of negative printing density on a projection densitometer designed to measure positive projection densities simplifies the problem of locating corresponding negative and positive areas, and eliminates the possible error that might arise from the use of two different instruments. The purpose of the work reported here is to establish a relation between diffuse and specular density for certain photographic materials.

The projection densitometer used was designed to approximate the optical system used for projecting motion pictures (Fig. 1). Neither the incident beam nor the measured component is strictly

TABLE I

*Par Speed Motion Picture Negative*

| $d_{\#}$ | $d_{\|\|}$ | $d_{\|\|}/d_{\#}$ | $d_{\#}$ calc. | $e$ | $T_s/T_t$ |
|---|---|---|---|---|---|
| 0.0641 | 0.108 | 1.68 | 0.0647 | +0.94% | 0.095 |
| 0.110 | 0.180 | 1.64 | 0.113 | +2.8 | 0.146 |
| 0.223 | 0.332 | 1.49 | 0.220 | —1.3 | 0.228 |
| 0.355 | 0.509 | 1.41 | 0.350 | —1.4 | 0.307 |
| 0.460 | 0.650 | 1.41 | 0.457 | —0.66 | 0.360 |
| 0.550 | 0.770 | 1.40 | 0.549 | —0.18 | 0.400 |
| 0.640 | 0.891 | 1.39 | 0.644 | +0.62 | 0.450 |
| 0.790 | 1.07 | 1.36 | 0.785 | —0.64 | 0.482 |
| 1.08 | 1.44 | 1.37 | 1.09 | 0.92 | 0.563 |
| 1.31 | 1.75 | 1.34 | 1.34 | +2.2 | 0.610 |
| 1.58 | 2.00 | 1.25 | 1.55 | —1.9 | 0.646 |
| 1.89 | 2.40 | 1.27 | 1.89 | +0.0 | 0.697 |

parallel. It is interesting to note, however, that the deviation from parallelism was so slight that a check of this instrument, made with the bench photometer using collimated light, showed no difference in density readings.

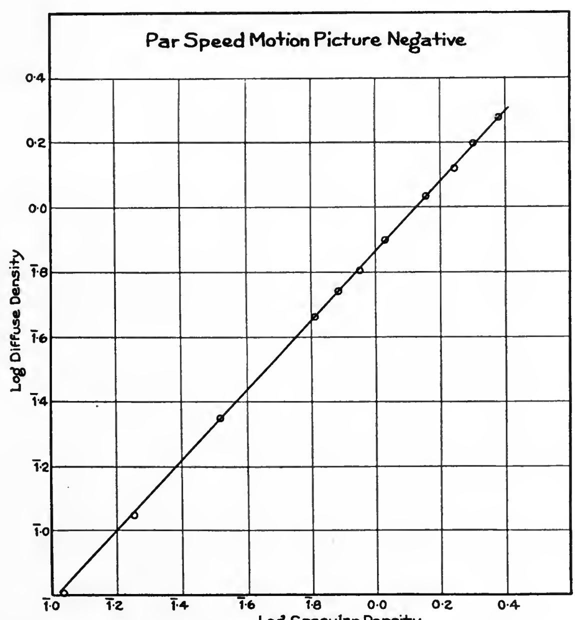


FIG. 3. Curve plotted from data of Table I.

**TABLE II**

*Motion Picture Positive*

| $d_{\#}$ | $d_{\Vert}$ | $d_{\Vert}/d_{\#}$ | $d_{\#}$ calc. | $e$ | $T_s/T_t$ |
|---|---|---|---|---|---|
| 0.0484 | 0.0697 | 1.44 | 0.0483 | —0.21% | 0.046 |
| 0.105 | 0.152 | 1.44 | 0.108 | +2.8 | 0.096 |
| 0.230 | 0.316 | 1.37 | 0.231 | +0.43 | 0.180 |
| 0.385 | 0.523 | 1.36 | 0.390 | +1.3 | 0.267 |
| 0.438 | 0.590 | 1.34 | 0.442 | +0.91 | 0.288 |
| 0.485 | 0.651 | 1.34 | 0.489 | +0.82 | 0.310 |
| 0.565 | 0.761 | 1.35 | 0.575 | +1.7 | 0.343 |
| 0.689 | 0.902 | 1.31 | 0.686 | —0.44 | 0.391 |
| 0.770 | 1.01 | 1.32 | 0.771 | +0.13 | 0.423 |
| 0.956 | 1.23 | 1.29 | 0.946 | —1.1 | 0.477 |
| 0.982 | 1.27 | 1.29 | 0.978 | —0.41 | 0.493 |
| 1.50 | 1.95 | 1.30 | 1.52 | +1.3 | 0.620 |

A form of integrating densitometer (Fig. 2) was chosen to make the so-called "diffuse density" measurements, because from its nature it actually measured the total transmitted light. This instrument makes use of the same Martens polarization photometer mounted

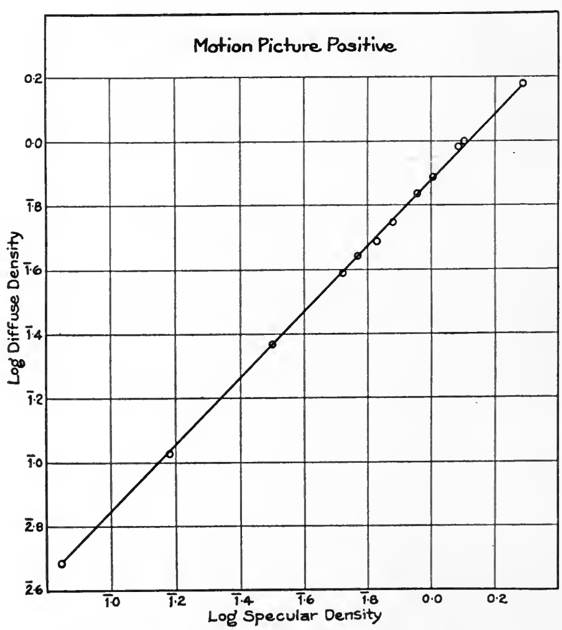


FIG. 4. Curve plotted from data of Table II.

**TABLE III**
*Eastman 40*

| $d_{\#}$ | $d_{\|}$ | $d_{\|}/d_{\#}$ | $d_{\#}$ calc. | $e$ | $T_s/T_t$ |
|---|---|---|---|---|---|
| 0.0650 | 0.101 | 1.55 | 0.0631 | —2.9% | 0.084 |
| 0.113 | 0.175 | 1.55 | 0.155 | +1.7 | 0.125 |
| 0.230 | 0.332 | 1.44 | 0.231 | +0.43 | 0.208 |
| 0.553 | 0.740 | 1.34 | 0.553 | 0.0 | 0.350 |
| 0.940 | 1.23 | 1.31 | 0.964 | +2.6 | 0.459 |
| 1.11 | 1.40 | 1.26 | 1.11 | 0.0 | 0.486 |
| 1.24 | 1.53 | 1.23 | 1.22 | —1.6 | 0.510 |
| 1.35 | 1.61 | 1.19 | 1.29 | +4.6 | 0.520 |
| 1.41 | 1.75 | 1.24 | 1.41 | 0.0 | 0.531 |
| 1.65 | 1.95 | 1.18 | 1.59 | —3.6 | 0.564 |

in the same supporting unit as is used with the projection densitometer. The essential difference between the two instruments is in the measurement of transmitted flux.

A number of densities ranging from 0.05 to 2.00 were prepared and measured on both instruments. Tables I, II, and III give the average of five readings for each density. Column 3 gives the ratio

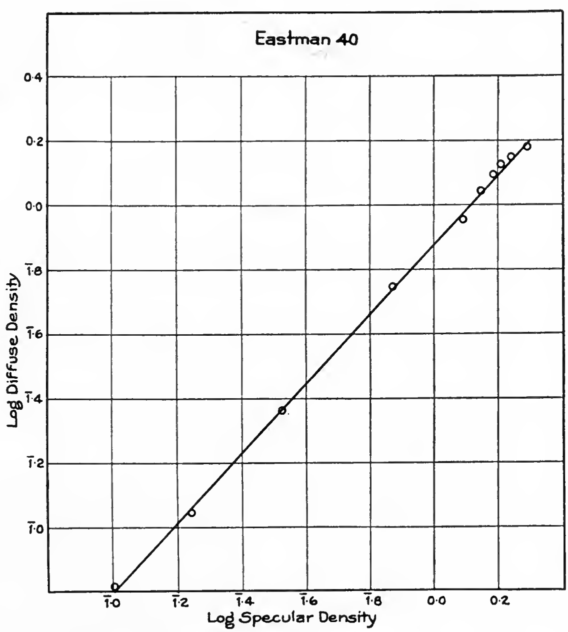


FIG. 5. Curve plotted from data of Table III.

of specular to diffuse density—the Callier $Q$-factor. Evidently a linear relation will not satisfy the data. The variation of $Q$ is about thirty per cent. The data seem to be very much more applicable to an exponential equation, such as was suggested by Renwick and Bloch (*loc. cit.*).

Figs. 3, 4, and 5 show the data of Tables I, II, and III plotted logarithmically. A straight line represents the locus of $\log d_{||}/\log d_{\#}$, with a maximum error less than the error of measurement.

The equation of these curves is of the form,

$$\log d_{\#} = m \log d_{||} - c$$

$$\text{or} \quad d_{\#} = d_{||}^{m}/\text{antilog } c$$

where $m$ is the slope and $c$ the intercept.

The values of these constants for the three emulsions investigated are as follows:

| | $m$ | Antilog $c$ |
|---|---|---|
| Par Speed Motion Picture Neg. | 1.088 | 1.37 |
| Motion Picture Positive | 1.036 | 1.31 |
| Eastman 40 | 1.091 | 1.30 |

The values of $d_{\#}$ as calculated from $d_{||}$ by the formula are given in column 4 (Tables I, II, and III), and the difference of percentage ($e$) between the observed and calculated values in column 5.

A number of samples of motion picture negative emulsion were developed for different times, the gamma (the slope of the Hurter and Driffield characteristic curve) being varied from 0.4 to 1.0 in order to determine the effect of the development upon the ratio of the specular to the diffuse density. It was concluded that the effect within this range was negligible. Three sets of motion picture negative densities representing three different batches of the same kind of emulsion were tested, and the results were in very good agreement. It is doubtful, however, whether the constants $m$ and $c$ will hold with equal accuracy for all batches of the same emulsion, since the average grain size differs slightly from batch to batch.

In column 5 of Tables I, II, and III is given the ratio of the scattered transmitted light to the total transmitted light as determined from the density values. The increase of this ratio is practically constant with respect to decreasing transmission values from 100 to 30 per cent.

The relation of the scatter ratio to the density is not linear even for low values of density, as was observed by Eggert and Archenhold,[6]

and therefore is not linearly proportional to the mass of the scattering material present. It is possible that the scatter ratio may be some function of the perimeter of the interstices between the silver particles, and it is hoped that by the use of single grain layers, some such correlation may be found.

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# MODEL MAKING WITH SHEET FILM BASE*

K. HICKMAN AND D. E. HYNDMAN

***Summary.***—*The paper describes methods of using sheet film base in making models for experimental processes. Methods of cutting and scraping the material are described at length, as also the manner of making and using the requisite thick and thin cements employed in making welds. Various illustrations are given in order to exemplify the processes.*

Experimenters in the time of Newton or Priestley were proud to boast that, from a jam jar, some string, and a piece of sealing wax, they could construct most of their physical apparatus.

Nowadays, although our laboratories are supplied with a variety of intricate devices and pieces of glassware, many problems demand the construction of special apparatus. The methods at our disposal vary with our constructive skill, but rarely embrace more than carpentering, glass blowing, soldering and sheet metal working, plumbing, and elementary electric wiring.

Of these, with the advent of Pyrex, it may be said that glass working is probably the most useful, and the least dispensable. To be able to see what is happening inside the apparatus is the great advantage, outweighing a hundred minor drawbacks. If metal working could produce transparent articles, the value of soldering and plumbing would be greatly enhanced, and many experimental problems would be simplified. This article does not describe such a miracle, but it does compromise by showing how transparent cellulose compounds may be built into useful laboratory apparatus.

Transparent cellulosic sheeting is generally made from cellulose nitrate or cellulose acetate. The more usual nitrate material is commonly known as celluloid. Since, however, this is a trade name for a special product, we shall speak of the material as nitrate base or sheet; and refer to cellulose acetate sheeting as acetate base.

A word as to the properties of these two substances: nitrate sheet

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is a mixture of cellulose nitrates plasticized with camphor. It is not only inflammable, but it also decomposes in the absence of air. Decomposition begins between 140° and 170°C., and ignition occurs at a higher temperature. Below the boiling point of water it softens sufficiently for molding.

Acetate base, on the other hand, since it contains no camphor, is not so plastic or easily molded. It can be bent at a temperature of 100°C., and will retain its new shape when thus bent. It does not decompose spontaneously in the absence of air at temperatures below its ignition point, and it does not burn with special vigor. Hence its use for safety cinematograph film and home motion pictures. Both materials are softened by certain organic solvents, and two pieces may be stuck together by placing a drop of solvent between them and squeezing them into intimate contact. The solvent softens and partially dissolves the surfaces, and is then absorbed by the mass of the material as water is absorbed by gelatin. Later it evaporates. The process, however, can produce a good autogenous weld of a strength nearly equal to that of the original material.

Nitrate and acetate bases may be bent and welded into complicated shapes. Since they may be stuck to glass, elaborate apparatus may be built up of dimensions difficult to obtain with glass tubes alone. Examples will be described later.

Besides the inability to resist heat, neither material will withstand strong liquids. The vague term "strong liquids" may be applied to the following:

| *Nitrate Base* | *Acetate Base* |
|---|---|
| Concentrated nitric acid | Moderately concentrated acids |
| Concentrated hydrochloric acid | 2 per cent alkali |
| Concentrated sulfuric acid | Acetone |
| 10 per cent or stronger caustic alkali | Alcohol |
| Acetone | Ether |
| Alcohol | Amyl acetate |
| Amyl acetate | |

Both bases will withstand water, solutions of metallic salts, dilute acids, carbonates, benzene, chloroform, and xylene. Nitrate base will resist 20 per cent sulfuric acid indefinitely.

### CONSTRUCTION WITH NITRATE BASE

The operations involved in working with nitrate base are four in number, and are extremely simple.

They are

(1) Cutting
(2) Shaping
(3) Welding:
  (*a*) to like material,
  (*b*) to glass and other substances
(4) Laminating

Directions given below for nitrate base serve, in practically every instance, for acetate base.

(*1*) *Cutting.*—Nitrate sheet that is to be cemented perpendicularly to the surface of a second piece (Fig. 1) should never be cut. The scissors should be reserved for trimming the edges of finished articles. No matter how carefully the cut is made, the edge will deviate slightly from a straight line or pure curve. A convenient way to part nitrate or acetate sheeting is to draw a sharp point, in pencil fashion, along a straight edge. A "Moore" glass push-pin works well, and may be discarded when the point is blunt. Old razor blades are not suitable because they tend to depart from the marked line. When a good clean scratch has been made, the material is bent until, with a slight snap, it parts along the entire length. Circles are cut with the dividers, placing a piece of scrap sheet under the center leg so as to avoid making a large pivot hole. Two or three revolutions with the dividers leaning in the direction of travel will make a deep enough scratch. If the internal circle is to be used, two or three scratches are ruled tangentially to the circumference, and the outer portion is broken away. When it is the outer ring that is wanted, the inner circle must be detached by carefully applying pressure with the thumbs. It is better to work the material backward and forward than to apply excessive force.

Other shapes are easy to produce. An ellipse is made by guiding the cutting point with a loop of string held between two fixed pivots. Wavy contours are produced with French curves. The line is first built up with a grease pencil from various positions of the curve and is then retraced, still using the curve, with the sharp point.

(*2*) *Shaping.*—The many cellulose nitrate articles available commercially are evidence that with molds and dies any shape can be produced. Molds are not common in the laboratory, so that the shaping operation is generally limited to simple bending. Variations of the cube and the cylinder are practicable, but not of the sphere.

Three kinds of equipment are requisite for bending: a square metal bar, a selection of metal rods, and a vessel of hot water. The metal bar is perhaps the most useful.

The inflammable nature of nitrate base would suggest using hollow bars and tubes that could be warmed with steam from an electric kettle. We have found it safe, however, to use a Bunsen burner, making sure that the sheeting and cement are pushed out of the way.

The bar has available four edges and four sides. At least one edge should be rounded, forming part of a circle of about $^1/_{16}$-inch radius (Fig. 2). All four sides may be at right angles, or the bar may be a right-angled triangle. In this case the other two angles should be rounded as well. The bar is used to supply heat to the sheet, and no matter how sharp a bend is desired, there should be sufficient bearing surface to convey the heat.

The bar is warmed by waving the Bunsen flame along its length until the moistened finger just sizzles when touching the upper surface. The flame is now extinguished, and the sheet brought into contact with the bar. A line should previously have been ruled with the grease pencil where the bend is to be made. On no account should a scratch have been made. The ends of the sheet are grasped in the two hands, and when it has begun to yield, the regions near the bend should be pressed with wood strips, or smothered tightly with a cloth. When the desired angle has been attained, the sample is removed, taking care to maintain the angle until the material becomes cold (Fig. 3). The procedure is similar when making a less sharp bend around a rod.

Sometimes it is necessary to produce an irregular shape to fit some special contour. In Fig. 4 the pieces *a–a′* are similar and have two edges at right angles, while the third follows the special contour; *a* and *a′* form the side pieces to the angular strip *c*. Let us suppose it is necessary to bend *b* so that it may be cemented in place to complete the box. *b* is cut to a strip $^1/_4$ inch wider than called for, and at least an inch longer. Placing the piece *a* beside a bowl of water hotter than the hands can bear, *b* is held with pliers and immersed. In a minute it is withdrawn and given a quick pressure with the hands at *V* (Fig. 4a), and allowed to spring away again. It will have taken a slightly permanent shape. If it does not match the curve of *a* sufficiently, the warming and pressing are repeated until a slightly *exaggerated* bend is attained. The curves at *W*, *X*, *Y*, and *Z* now receive attention, exaggerating each one, in order, a little less than

its predecessor. In this way the final sample is found to have curves at the right places, but owing to its recovery in warm water, each curve is a little *less* pronounced than needed. This is an advantage, for when fixture is made at the point $T$ (Fig. 4*a*), pressure at $S$ brings the whole strip into contact with $a$ and allows the cementing to be accomplished in one operation.

(3) *Welding.* (*a*) *Autogenous: Base to Base.*—The requirements are *thin cement*, and *thick cement*, in suitable containers, and some *hog's hair brushes*, in holders from which the varnish has been scraped. The containers are easily made from 16-ounce wide necked bottles supplied with large corks that do not fit too tightly. Through a central hole in each cork a stout walled test tube, $^3/_4$ inch in diameter and 6 inches long, is pushed from below. This is much better than having the brush itself fixed in the cork (Fig. 5).

Many formulas for film cement have been published, but since only small quantities are needed, we have found it convenient to use the ready-made Eastman cement without inquiring into its composition. This is the thin cement referred to above.

The thick variety is made by dissolving scrap base, cut into strips an inch and a half long by $^1/_{16}$-inch wide, in the thin cement. A spare bottle is filled one-third full of the chips and cement is poured in until the bottle is more than half filled. The mixture is stirred vigorosly with a stout glass rod every ten minutes throughout the day and left to settle overnight. In the morning the clear thick syrup is decanted into the container from a slight residue of gelatinized strips. A brush is selected, placed in the syrup, and the cork thrust home.

It should be understood at the outset that nitrate sheet sticks to itself by virtue of its own powers of adherence. The cement is used merely to prepare the surfaces. After these have momentarily been flooded, the best joins are obtained when the surfaces are pressed together tightly enough to extrude every trace of unabsorbed liquid. Obviously, the thick cement will not be pressed out as efficiently as the thin, and will therefore not make as good a join. The thick fluid should therefore be used for external reinforcement of the join.

Joins are of two kinds, perpendicular and parallel, or end to face and face to face. The latter is lamination on a small scale.

The parallel join is very easy to make. One sample is stood at an angle on the other, and a few drops of cement from a pipette or a brush are laid in position. The upper sample is quickly laid down

and an even pressure applied all over with the flat of the hand or a cloth pad. A piece of blotting paper placed underneath will absorb the excess cement pressed from the edges. The operations are shown in Figs. 6 and 7, while the finished join is being tested in Fig. 8.

The perpendicular join is more difficult but is much more useful. At its simplest, the straight edge of a piece of base is pressed tightly against the surface of another piece, while a little thin cement is run along the angle at each side (Fig. 9). The pressure is maintained for 30 seconds after all trace of liquid has disappeared, and the sample left undisturbed for an hour. It is then held in an inclined position (Fig. 10), while a drop of thin cement is placed at the top of the angle on each side and allowed to run down, which it should do quickly. Immediately a big drop of thick cement is placed in the same position and allowed to fall slowly along each crevice. At every inch or two of fall it should be replenished, not at the top, but at the head of the traveling drop. Finally the sample is put away to dry for one day on a level surface, after which a section of the join should present the appearance in Fig. 11. The object of the pre-wetting with thin cement is to prevent the inclusion of air bubbles.

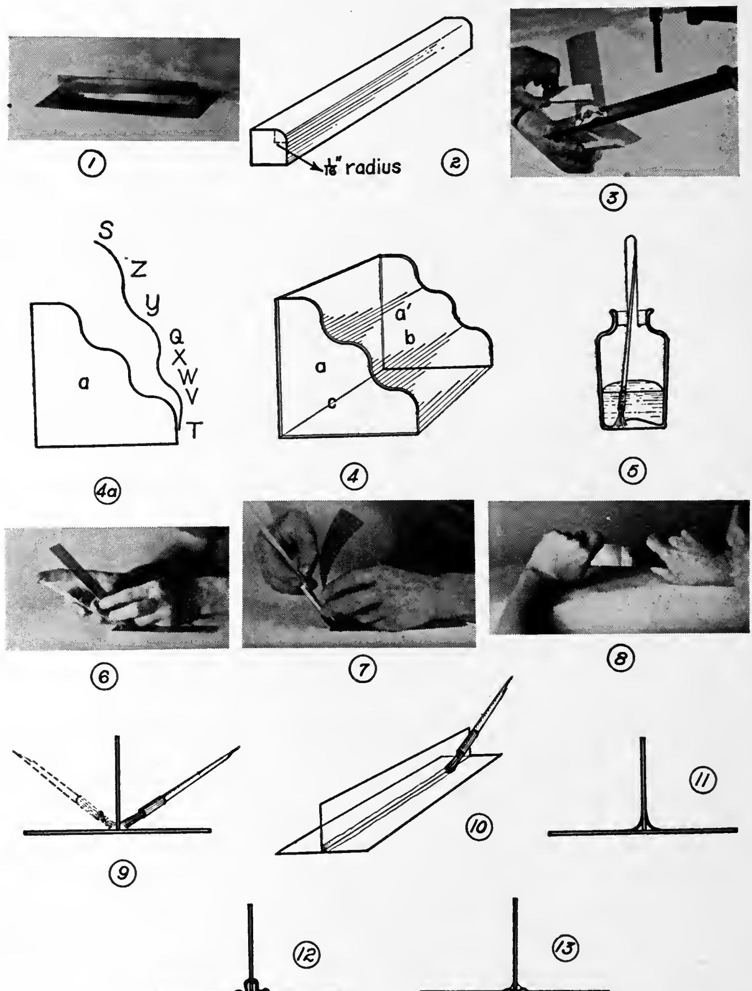
If the thick cement had been applied to the corner with a brush, it would have formed ridges where they were least needed, yielding a finished product like Fig. 12.

The reinforcing cement must be used with caution. It sets after partially drying into the shape of the join, but later when more solvent has evaporated it contracts and pulls the pieces into a more acute angle than was intended. The reinforcing should always be done on two sides of the join and sometimes, if the appearance of Fig. 13 is to be avoided, on three. The properly finished join is shown in Fig. 11.

Most perpendicular joins are less simple. They are the kind involved when an end, a side, or a partition is cemented to a shaped container. Fitting a circular disk into the end of a cylinder is perhaps the simplest case. The disk, cut to fit tightly, is pushed into place and thin cement is run all round. Since there is no tendency for the join to come apart, the thick cement may follow immediately. A large globule is placed in one crevice, and the cylinder is rotated until the syrup has fallen all around. The other side is then treated.

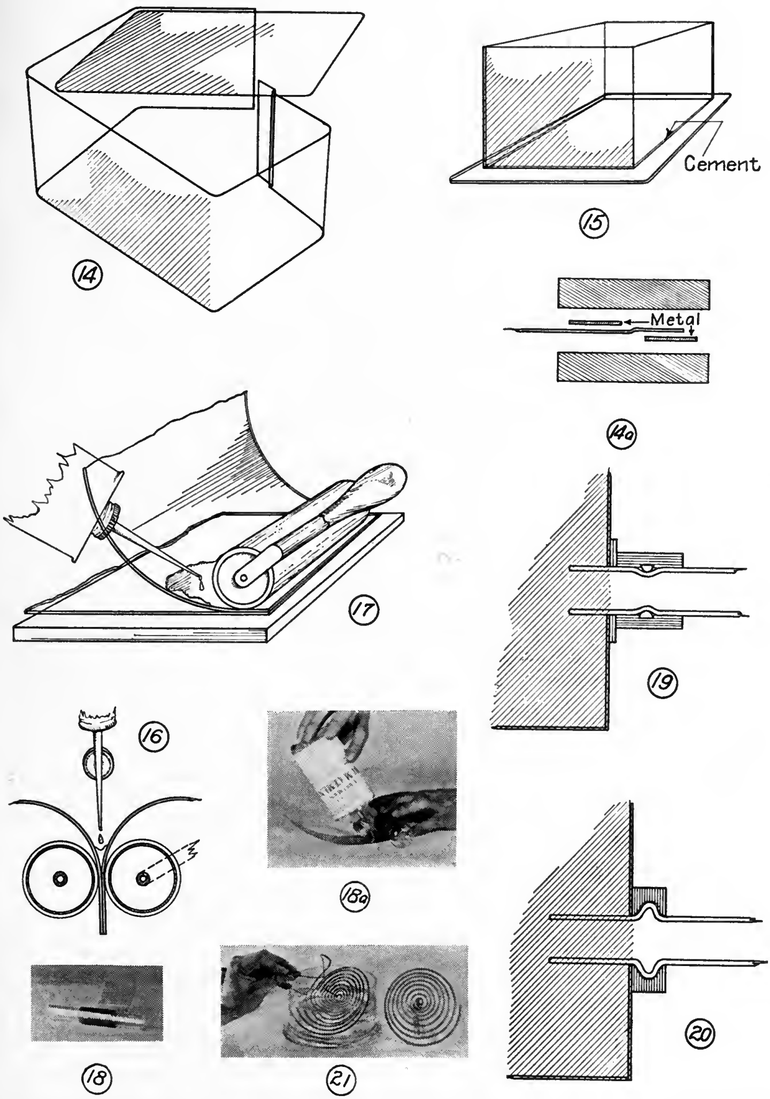
Fastening the end into a rectangular box is a little more difficult. The sides of the box may be completed before or after insertion of the end. In the first case, the end piece is cut accurately to size, but

the corners are rounded off more than would appear necessary. It is thrust into position and cement applied at the center of the long sides, holding them against the end piece for at least a couple of minutes. The centers of the short sides next receive treatment, and cement is finally brushed all around. One hour should elapse before the application of the thick cement.




FIGS. 1–13, INCLUSIVE. Illustrating the manner of making the various kinds of joins.

When the rectangular box is to be built around the end piece, it should be fitted by trial and error before any cementing is done. The join is most conveniently made in the middle of a long side.




FIGS. 14–21, INCLUSIVE. Illustrating the procedure of making more complicated constructions.

Cementing of the top plate is begun with one-half of the split long side (Fig. 14), being careful that the plate is pushed snugly up to the corner. After a few minutes, the other sides may be brought into position and secured. Finally the free half of the split side, previously given a rebate by pressing between two thin metal plates in a vise (Fig. 14*a*), is cemented in place and a parallel joint made all the way down The simplest way of all of closing the rectangle is to stand it on a plate larger than actually required, run cement all around the crack, and follow this, within and without, by thick cement (Fig. 15).

(4) *Lamination.*—Although joining sheet to glass and other materials is next in order for consideration, it will be convenient first to describe lamination. If two thin sheets be placed face to face, with their ends between the rollers of a horizontal mangle (Fig. 16), cement may be poured into the junction and they may then be rolled into one homogeneous piece. In place of a mangle one may use a drawing board and a gelatin composition roller of the kind favored by printers for inking up halftone blocks (Fig. 17). With a ten-inch roller pieces 9 by 20 inches may be built up with ease. One sheet 11 by 25 inches is laid on the board. A thin line of cement drops is placed at one end, and a second sheet secured above it along this edge. Holding the upper sheet at an angle of 45 degree, a liberal pool of cement is poured into the angle, after which the roller is pushed smoothly but quickly forward. Enough cement must be used to stick the entire length. It is convenient to squirt the liquid from the original can.

Laminating is a messy operation. The cement exudes from sides and end and is very likely to get on the board or under the clean bottom face of the nitrate base. This may be prevented by doing the operation on blotting paper. It is important that the freshly laminated material should have the uncemented side portions cut away at once. It should be allowed to hang vertically for some hours, because any bend suffered at this stage will impose a permanent curvature.

Nitrate base is readily obtained in thicknesses of 5, 10, and 20 thousandths of an inch. The 20-thousandths sheet is the most useful, and by laminating two or three thicknesses, a sheet sturdy enough for most requirements can be made.

The need is soon encountered for nitrate tubing. Unfortunately, we have been unable to obtain this in lots of less than 50 pounds,

and have been forced to make it by lamination, or else press glass tubing in service. Short lengths can be made very simply after the manner shown in Figs. 18 and 18*a*. Cement must not get between the pyroxylin and the glass, otherwise the mandrel can not be withdrawn.

(*3b*) *Welding Nitrate Base to Other Materials.*—The base does not make good shafts or bearings, or good narrow tubes. Whenever moving parts are involved, or fluids have to be conveyed to containers, glass or metal spindles or tubes have to be affixed to the sheeting.

Nitrate base cemented to smooth glass or metal adheres fairly well until one corner becomes lifted. Then any slight strain strips

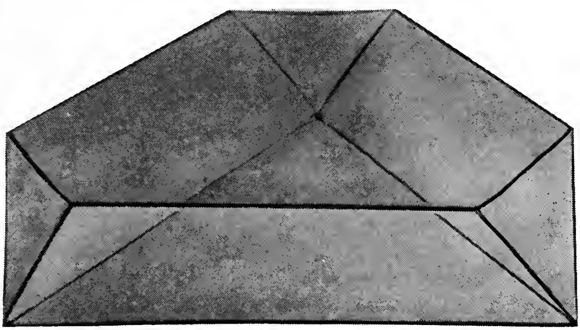


FIG. 22. Transparent crystal model.

it away. This happens particularly easily under water. Consequently the base and glass (or metal) have to be so shaped that the one surrounds the other completely and without the possibility of rotation.

*Cementing a Glass Tube into a Nitrate Container.*—Two methods have been used successfully. In the first, the glass is indented in the blow pipe flame and when cold a chip of base is thrust into the cavity. A thick tube is then laminated over this, wetting the glass with much cement. When the walls are a quarter of an inch thick, the whole assembly is cemented to the side of the vessel. Fig. 19 shows the procedure in detail.

The other method involves an unsymmetrical expansion in the glass so as to make the grip secure. A flat uneven bulb is blown, and a number of washers are cut to fit its contours, the outer ones just

fitting the undistorted tube. These are cemented in position one by one, giving the effect shown in Fig. 20. Such built up collars make extremely strong joins. Shafts may be pushed through nitrate Pelton wheels, or film developing drums, and secured at each contact by some modification of the procedure. Good contact can often be made between a glass tube and a single plate of the rotor by merely denting the glass at the junction and painting it liberally with thick cement. This dries into the hollow and produces firm adhesion.

Steel and copper offer no especial difficulties except that the cement must on no account contain acetic or other acid.

A device that has proved useful is shown in Fig. 21. A spiral of

FIG. 23. Model of film developing drum.

narrow nitrate tube was wanted. Accordingly, a coil of fine copper piping, having an outside diameter equal to the internal diameter of the finished tube, was wound into a well-spaced spiral and supported by a wire handle. It was then dipped about 30 times into thick nitrate cement, allowing at least three hours for drying between successive dips. The dipping required rigid adherence to a certain sequence of operations. First, the spiral was dipped with a slanting motion into thin cement and quickly withdrawn. It was then instantly lowered *slowly* in a slanting manner into the thick cement. When under the surface it was rotated through 180 degrees and removed at an angle, being careful that each convolution left the surface without forming a drop. Once out in the air, it was rotated in all directions for a minute or two until the new layer had set. It was then hung up to dry.

After the thirtieth coat, it was dried for a day in the 60°C. oven. The copper spiral was then dissolved out with 1:1 nitric acid. This was a tedious operation, owing to the driving of the acid out of the spiral by the gases formed. It has to be done quickly or degradation of the nitrate base sets in. Finally, when the copper was entirely removed, a mixture of water with 25 per cent industrial alcohol was drawn through, a few cc. per minute, for a day. The spiral, when

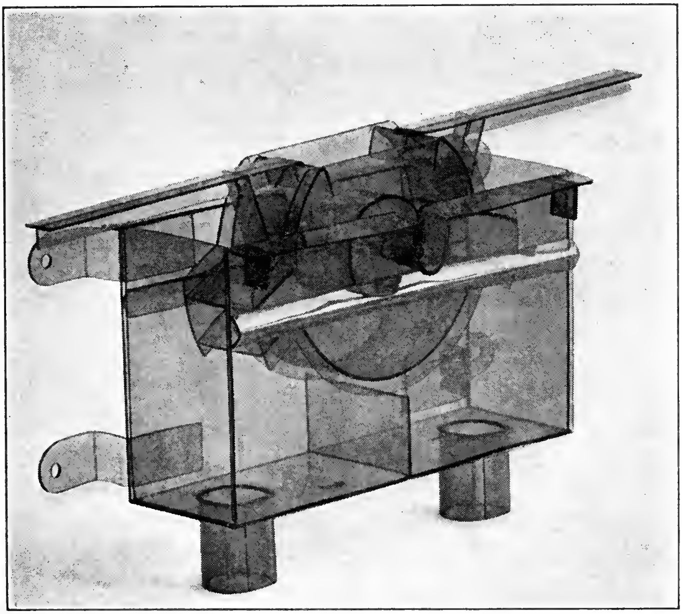


FIG. 24. Complex model of industrial instrument.

dried, served its purpose sufficiently well. One is shown, minus the copper core, at the right of Fig. 21.

*Strength and Rigidity.*—Thin nitrate sheet is too flexible to be mechanically rigid unless it is bent and secured in many directions. A careful design will include sufficient cross pieces. When these are not admissible, right-angle struts and bracings may be put across the straight sides. They will be observed in some of the later figures.

*Tinting.*—Both nitrate and acetate base may be colored by dyes dissolved in a mixture of alcohol and acetone. The particular mix-

ture of solvents must be found to suit the individual worker. Generally speaking, the more acetone, the more strongly the color will take.

*Sphere of Usefulness.*—In the laboratory we have found the construction described here useful for making:

Models of crystals and atoms, where it is desired to see top, bottom, and contents, all at the same time (Fig. 22).

Film developing drums, for use in those photographic researches where it is inadvisable to let the developer touch anything but glass and film substance (Fig. 23).

Containers in hydraulic systems, where it is necessary to observe the path taken by the water.

Certain industrial instruments, where the solutions attack metals (Fig. 24).

A more ambitious use is found in the construction of architects' models, and for the building of miniature movie sets. The architect has, in the past, been content to build his miniatures from pasteboard which, though excellent for exteriors, gives the patron little idea of the internal lay-out. It is possible to build cottages or even towns from nitrate or acetate stock, and show a superior external surface and a full view of the interior arrangements.

*A Word of Caution.*—Acetate sheeting is generally a trifle less transparent and less easy to work than nitrate sheeting. It is to be preferred, however, for all large construction work because of its safety. Both materials shrink with age, the contraction being most marked at the joints. The less liberally the solvent or cement is applied during construction, the less serious will be the distortion. Simple pieces of apparatus may have a life of years, but heavy cemented pieces of unusual shape are likely to present a distorted appearance at the end of a few months.

# THE DEPICTING OF MOTION PRIOR TO THE ADVENT OF THE SCREEN

EARL THEISEN*

***Summary.***—*The motion picture as it is known today has existed less than fifty years but certain of the principles which underlie its development can be traced back many years more. This paper represents an attempt to list chronologically the chief devices and inventions pre-dating the motion picture equipment of 1895.*

**25,000 B.C.**—The earliest known example of motion expressed pictorially was found in a cave at Altamira, Spain, representing a trotting bear having two sets of legs, probably an attempt to represent the one set of legs in two different positions; the relic was found in rocks of the Upper Paleolithic period, and probably was the work of a Cro-Magnon.[1]

**5000 B.C.** *et seq.*—*Ombres Chinois*, "Chinese Shadow Shows." All races have evolved shadow shows, indicating the general thought to represent motion pictorially. Records exist of shadow shows in Egypt and India before the time of Christ. Historical records indicate that in Java shadow shows were included in every festival. The shadow shows, termed *wajang*, employed miniature figures grotesquely made of leather, cardboard, wood, or other materials, the shows revolving about the Javanese customs and myths, gods and devils. The operator, or *gamelong*, manipulates the figures before a fire, so as to throw the shadows of the figures upon a screen, accompanying the movements with suitable conversation and music furnished by reeds and gongs. The audience, squatted before the screen, views a realistic representation of the conflicts between gods and devils.

In France, in 1767, Seraphim presented shadow shows by means of a magic lantern. The series was popularly known as Chinese Shadow Shows, or *Ombres Chinois*. Caran d'Ache developed these shows further, establishing them as *French Shows*, and presented historical tableaus. Color was introduced by Henri

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Rivière by adding colored bits to the figures; he tried also to arrange the figures so as to provide perspective in the shadows by using two lanterns so arranged as to present dissolving views.[2,3,4,5]

**65 B.C.**—Titus Lucretius Carus[6] in *De Rerum Natura* wrote as follows:

> "Do not thou moreover wonder that the images appear to move,
> And appear in one order and time their legs and arms to use.
> For one disappears, and instead of it appears another,
> Arranged in another way, and now appears each gesture to alter,
> For you must understand that this takes place in the quickest time."

This is probably the earliest recorded discussion of pictorially represented motion. From this record it would seem that some kind of device for depicting motion existed at that time.

**130 A.D.**—A record of this date of a device for depicting motion exists in the Bodleian Library, Oxford.[7]

**1640 A.D.**—About this time the *Magia Catoptrica*, also known as the *Megaloscope*, was invented by Athanasius Kircher. This device was a lantern, similar to the present-day magic lantern, with which were projected drawings. A favorite subject for projection was a drawing of the devil with his trident. Kircher wrote a book entitled *Ars Magna Lucis et Umbrae* (Great Art of Light and Shadow) in 1646.[1]

**1806.**—Henry L. Child's invention of the *Phantasmagoria*, or *Bi-Unial Lantern*, was announced about this time. The device was used to entertain audiences nightly at the Sanspareil Theater, London, now known as the Adelphi. Subsequently there appeared a great number of magic lanterns and slide-shows of hand-drawn transparencies.

**1824** (Dec. 9).—Peter Mark Roget read before the Royal Society in London a paper describing the principle of persistence of vision, using for illustration a revolving and progressing wheel, the spokes of which could be seen through a vertical aperture placed in front of the wheel.[8]

**1826.**—The *Thaumatrope* was invented about this time by John Ayrton Paris.[9] This device was similar to one made several months before by Dr. W. H. Fitton at the suggestion of Sir John Herschel.[10] It consisted of a cardboard disk with two strings attached to the edges. One side showed the picture of a bird, the other side a picture of a bird-cage. Upon spinning the disk, the bird appeared to the onlookers as though it were in the cage. This is said to be the first device that depended for its operation upon the persistence of vision.

**1831.**—The physical and visual phenomena of motion were studied by Michael Faraday, in England, by means of a series of geared wheels, one combination being known as "Faraday's Wheel."[11]

**1831.**—The *Phenakistoscope,* later known as the *Phantascope,* was invented by Joseph Antoine Ferdinand Plateau.[12] This device was composed of two disks revolving together on a single shaft; one disk had a series of slits around its periphery, the other a series of drawings, in phases, of a complete movement or action. When the disks, containing the slits and drawings, were revolved, the appearance of motion was obtained by looking through successive slits as they passed a given point. Plateau, in Belgium in 1843, lost his sight as a result of his experiments in vision.

**1832.**—A *Stroboscopic Device* was invented by Dr. Simon Ritter von Stampfer, in Austria, which was identical with Plateau's device, although Plateau and von Stampfer worked independently of each other.

**1834.**—The *Daedaleum,* or *Wheel of the Devil,* was invented by William George Horner, of England. This device was a slitted cylinder, mounted on a stand, through the slits of which could be seen drawings mounted within.

**1850.**—Perret and Lacroix improved the *Phantascope* by adding to it a front-slotted disk, the first to be used.

**1853.**—Kircher's magic lantern and von Stampfer's motion device were combined into a single instrument by Lieut. Baron Franz von Uchatius, for the purpose of showing the trajectory of bullets; this was the first time that pictures showing motion were projected.

**1860.**—The *Zoötrope,* or *Wheel of Life,* was patented in France by Desvignes. This device should probably be regarded as the forerunner of the motion picture due to its great popularity at this time. Galloping horses formed the favorite subject for exhibition.[13]

**1861.**—Dumont patented in England a device for exhibiting motion that consisted of a series of photographs arranged as facets on a prismatic drum made of glass.[14]

**1861** (Feb. 5).—Coleman Sellers patented in the United States the *Kinematoscope.*[15] Photographs of his children were made in successive phases of action by means of a camera having two lenses, the photographs thus being stereoscopic; these photographs were then mounted *seriatim* on the blades of a paddle, and were viewed through a stereoscope while moving away from the viewer as the paddle was turned by hand. Action was thus built up during the exposure pose

by pose; the wet plates were kept moist with glycerin between poses, dry plates having not yet been invented. In the name of this instrument the word *kinema* was used for the first time in connection with pictures of moving objects.

**1864** (Apr. 25).—Louis Arthur Ducos du Hauron was granted a French patent on a device operating on the principle of persistence of vision.

**1865.**—In France, Omnius and Martin photographed the beating heart of an animal, recording the beats in diagrammatic form.

**1866.**—J. A. R. Rudge succeeded in photographing successive phases of motion; exhibiting in 1868 the scenes so taken with his *Bio-Phantascope,* or lantern. Two of the mechanisms, notably a shutter and an intermittent movement used by him in the design of this lantern projector, are similar in principle to those employed later by others in connection with motion picture apparatus. Rudge, in 1885, became associated with Friese-Greene.

**1866.**—Beale invented the *Choreutoscope.*[1]

**1867** (Apr. 23).—A patent was granted to William Lincoln in the United States on a device known as the *Zoötrope,* similar to Desvignes' device.[16,17]

**1869.**—Linnet patented his *Kineograph,* a device in the form of a book, for showing pictures of moving objects. The principle of this device was employed in the Biograph Company's *Mutoscope.*

**1869.**—Trevor patented a system of taking radial photographs rapidly on glass.

**1870** (Feb. 5).—The *Phasmatrope,* invented by Henry Renno Heyl, was exhibited on this date at the Academy of Music at Philadelphia. It was a device having pictures on glass, mounted radially on a wheel, which pictures were exposed successively and intermittently to the rays of a lantern by a cam and pawl mechanism. The instrument embodied many of the principles of the present-day projector. As his first subject Heyl chose a pair of dancers waltzing, the results being exhibited at the Academy to an audience of 1600 persons.[18]

**1871.**—Thomas Ross announced his *Wheel of Life.*

**1872.**—At Leland Stanford University, Eadweard Muybridge produced photographs of trotting horses, using five cameras placed side by side. The culmination of his experimental work occurred in collaboration with John D. Isaacs.[19]

**1874.**—Janssen developed the *photographic pistol,* employing a

single lens and one plate; it was used for astronomical purposes only, particularly for taking pictures of the planet Venus in its successive phases.[20]

**1876.**—A device for tripping cameras, somewhat similar in arrangement to the electrical door-bell, was developed by John D. Isaacs, working in conjunction with Muybridge. In this device was used a shutter patented in England in 1856 by Thomas Skaife. The number of cameras used for photographing the trotting horses was increased from five to twelve, then finally to twenty-four. These cameras faced a white background forty feet long. As the cameras were side by side, the horses would appear, when the pictures were projected, as though they were kicking past the background.[18]

**1877.**—Emile Reynaud devised the *Praxinoscope*, for projecting upon a screen pictures drawn on a continuous band of a substance called *crystalloid.* The first subject so produced was *Poor Pierrot,* which was first exhibited at the "Reynaud Electrical Theater." Reynaud also developed a device similar to the Zoötrope, with a central drum of faceted mirrors.[21]

**1877.**—Jean Louis Messonier made transparencies of Muybridge's horse-pictures, which were mounted on a glass disk rotating before a slotted opaque disk and illuminated by a lantern. This device was known as the *Zoöpraxoscope.*

**1882.**—Dr. E. J. Marey developed the *photographic gun.* This device registered on a glass plate 12 successive pictures of white figures against a black background at a speed of $^1/_{200}$th second for each picture.[20, 22, 23]

**1882.**—Van Hoevenbergh was granted a patent on a card-flipping device.[24]

**1885.**—William Friese-Greene exhibited pictures of successive phases of motion, photographed by the Marey method on a single glass plate. In 1888 he began to experiment with transparent sensitive paper; and in 1889, applied jointly with Mortimer Evans for a British patent, using conceptional drawings, from which the apparatus was later constructed. He was also granted a British patent[25] on stereo-motion pictures in 1893, and a color patent[26] in 1898.[1, 27, 28]

**1886** (Nov.).—Louis A. A. Le Prince applied for an American patent on a camera having sixteen lenses or less (specification calls for sixteen lenses). On Jan. 10, 1888, a patent[29] was granted, eliminating claims on one- and two-lens cameras because of the interference of

Dumont's British patent[14] of 1861. On Nov. 16, 1888, a British patent was granted to Le Prince on a single- and multiple-lens camera and projector, using the Geneva movement. Although the Le Prince camera was never exploited, Le Prince experimented with sensitized paper and gelatin bands for film until the fall of 1889, when he is said to have obtained sensitized celluloid.[30]

**1887.**—Edison, assisted by W. K. L. Dickson, began his experiments with motion devices. In August, 1889, he obtained a short length of sensitized rollable film on a nitrocellulose base from George Eastman.[31] The *Kinetoscope*, employing a non-intermittent movement, was demonstrated at West Orange, N. J., on Oct. 6, 1889. A patent[32] was applied for on a camera in August, 1891, and granted in August, 1897. The peep-show Kinetoscope began its commercial exhibits at 1155 Broadway, New York, N. Y., on April 14, 1894, at the Holland Brothers' Peep-Show Parlor. In April, 1896, Edison acquired the Jenkins-Armat and Armat projector patents, constructed a projector, and began exhibits at Koster and Bial's Music Hall during the week of April 23, 1896. The *Projecting Kinetoscope* was made in 1897. The Edison camera of 1889 was capable of photographing forty pictures per second.[33] Edison's choice of the picture size and film width as well as four perforations to a frame are considered by many to have established these standards for the industry which later developed so rapidly.

**1888** (June 13).—Wallace Goold Levinson read a paper before the Brooklyn Academy of Photography, describing his invention, a wheel with photographic plates moving in sequence.

**1889.**—Anchütz devised the electrical *tachyscope*, a large wheel having pictures drawn about the rim.[1]

**1893–4.**—Exhibitions are claimed to have been given in Washington, D. C., by C. F. Jenkins, using a projector designed by himself and called the *Phantoscope.*[34] Mr. Jenkins is said to have begun experimenting in 1890 on cameras for photographing pictures in rapid succession and to have devised several with single- as well as multiple-lens systems. In 1893, he built the *Phantoscope** which used a beater movement.[35] On March 25, 1894, he entered into

* *The Photographic Times* (1894) contains a picture of the Phantoscope camera and a series of pictures made with it. Also the following ". . . the pictures are reproduced in an optical lantern upon any size screen, so rapidly that the eye does not see the pictures except as one continuous picture with the objects apparently in motion."

partnership with T. Armat for the purpose of constructing, exhibiting, and promoting the device. Models were constructed and taken to the Cotton States Exhibition in Atlanta, Georgia, in October, 1895.

**1894** (Feb. 5).—Two *Kinetoscope* films were projected by J. A. LeRoy before a group of about 25 persons assembled in H. Riley's Optical Shop, 16 Beekman St., New York. The projector used was designed and built by Mr. LeRoy who had previously (1893) built a projector which handled unperforated film.[36]

**1894** (Nov.).—Herman Casler obtained a patent[37] on a card-flipping device. Pictures of successive phases of motion were mounted on a geared hub. Several other patents were granted to Casler: on a sliding device that flipped pictures of successive phases of motion, Nov., 1895;[38] on a hand-shaken device with mounted pictures;[39] and in May, 1897, on a device[40] similar to Coleman Sellers' Kinematograph (1861), although Casler's device was not stereoscopic. In February, Casler obtained a patent[41] for the *Mutoscope.* The Casler patents were used by the American Biograph Company in their peep-show devices, as were the W. K. L. Dickson patents of September, 1897.[42]

The American Biograph Company, formed by H. N. Marvin, W. K. L. Dickson, E. B. Koopman, and Herman Casler, gave an exhibit with the *Mutoscope,* using a screen, at Hammerstein's Olympia Music Hall on Oct. 12, 1896. The *Mutoscope* contained a roller mechanism that intermittently squeezed the film to move it forward, then perforated the film while it was at rest, for the printing operation. Litigation later proved the Biograph friction movement to be the only one that did not infringe on the Edison and Edison-Armat patents.[43,44,45,46,47] Illustrations of the friction device known as the *web feeding device* and the Biograph apparatus as a whole can be found in the itemized patent specifications.

**1895** (Mar. 22).—Louis and August Lumière publicly demonstrated their *Cinematographe* on Mar. 22, 1895. A public exhibition, for which an admission fee was charged, took place at the Grand Café in Paris on Dec. 28, 1895. Using a planetary cam movement, the pictures were projected to a screen. The Lumières obtained celluloid from the United States and sensitized it. Their camera photographed sixteen pictures per second.[18]

**1895** (Apr. 21).—Woodville Latham with the assistance of E. A. Lauste completed the *Pantoptikon,* later known as the *Eidoloscope.* On Apr. 21, 1895, the first press exhibit of pictures projected to a

screen by this continuous-movement device was given at 35 Frankfort Street, New York, N. Y. On May 20, 1895, commercial exhibits began in a storeroom at 153 Broadway, New York. The patent specification[48] applied for June 1, 1896, lists a loop device later known as the *Latham Loop.* This patent was declared invalid in litigation, later, due to a prior reduction to practice by Thomas Armat.[49,50]

**1895** (Sept.).—Thomas Armat, continuing his experiments independently of C. F. Jenkins, completed the *Vitascope* projector, later commercially manufactured by Thomas A. Edison, after Edison had acquired from Armat certain patents on the Geneva star movement[51] and beater movement.[52] The first public exhibition of the *Vitascope* took place at Koster and Bial's Music Hall, April 23, 1896.[53]

**1895** (Oct.).—The Robert Paul projector was perfected, with the assistance of Birt Acres.[18] A demonstration was held at the Royal Institute, London, on Feb. 28, 1896. The first experiments concerned continuous movements, but finally the seven-point Maltese Cross was incorporated in the mechanism and successful exhibits were held.

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# THE HISTORY OF NITROCELLULOSE AS A FILM BASE

EARL THEISEN*

***Summary.***—*The following chronology deals with the evolution of motion pictures as produced photographically on a nitrocellulose support carrying a light-sensitive emulsion of one kind or another. Even though the later dates of the preceding chronology overlap the earlier dates of the one that follows, the two chronologies have been kept distinct in order to present the history of the nitrocellulose film base as a unit in itself.*

**1845-6.**—The discovery of the cellulose nitrates about this time is credited to Schoenbein, who became associated with Böttger sometime subsequently to August, 1846.[1,2]

**1847.**—The solubility of the cellulose nitrates, especially in alcohol and ether, was accurately investigated by Gladstone; these experiments no doubt led to the subsequent discovery of collodion.[1]

**1848.**—Iodized collodion was used by Frederick Archer Scott in his *calotype* wet-plate process.[3]

**1855.**—Alexander Parkes was granted an English patent on *parkesine,* a substance similar to collodion, made by mixing anhydrous wood alcohol with guncotton.[4]

**1868.**—Daniel Spill invented *xylonite,* a combination of pyroxylind, alcohol, and ether; he was associated with Parkes in some of his work.[5]

**1869.**—John W. Hyatt, of Newark, N. J., invented celluloid by combining collodion with camphor, for which he was granted a U. S. patent[6,7] on June 15, 1869; in the patent specifications the name *pyroxylin* was used. Numerous patents were granted to the Hyatt brothers covering various uses of this material as artificial ivory. The name *celluloid* first appeared in the U. S. Patent Gazette on July 2, 1872, in the name of the Celluloid Manufacturing Company, of Albany, N. Y., assignee of the various Hyatt patents.[8,9,10]

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**1876.**—On November 9 of this year, an English patent[11] was issued to Wordsworth Donisthorpe on the *Kinesograph*, a device to be used for taking photographs on glass plates arranged as a pack, each plate dropping out of the way of the succeeding plate after being exposed. Pictures were taken at the rate of eight a second. The patent specified that the pictures were to be finished on paper and spaced equidistantly thereon. Another patent was granted to Donisthorpe on August 15, 1889, specifying the use of an electric spark for providing intermittent illumination in a viewing device. In *La Nature*[12] appears the following description of Donisthorpe's work: "If the apparatus be arranged to take the successive pictures at sufficiently short intervals of time they may be printed at equal distances upon a continuous strip of paper; this paper, with the whole series of pictures upon it, may be used in the instrument known as the *Zoötrope* or *Phenakistoscope*. . . this strip may be wound on a cylinder, to be unwound from it at a uniform speed to another cylinder, and so carried on past the eye of the observer, any ordinary means being used for insuring that the picture shall be exposed only momentarily to the observer. By this means the movements made by a person or group of persons, or any other object during the time they were being photographed, may be reproduced to the eye of the observer."[13]

**1884.**—W. H. Walker and George Eastman, on June 27, 1884, assigned to the Eastman Dry Plate & Film Company a patent application on the process of coating paper with an emulsion having a soluble under-coating so that it might be applied to a stripping process; granted in 1890.[14]

**1887.**—Hannibal Goodwin, in May of this year, applied for a U. S. patent on a method of preparing a celluloid support for photographic emulsions, the title being "Photographic Pellicle and Method for Producing Same." The patent[15] was granted on September 13, 1898; it is said that Goodwin did not reduce it to practice. This patent was later the subject of lengthy litigation, which was ultimately decided in favor of Goodwin's successors.[16,17]

**1888.**—John Carbutt, in Philadelphia, began the commercial manufacture of films coated on sheet celluloid, obtained from a company in Newark, N. J. He apparently experimented with this product for two or three years before he could make it commercially.[18,19]

**1888.**—Wallace Gould Levinson on June 26 applied for a U. S. patent,[20] which was subsequently granted, describing further developments along these lines.

**1889.**—On April 9, Harry M. Reichenbach applied for a U. S. patent, which was granted on December 10, on a method of making transparent sheets of celluloid; a mixture of methyl alcohol, camphor, nitrocellulose, amyl acetate, and fusel oil was dried on a polished support, after which it was stripped off and coated with the photographic emulsion. This patent was assigned to the Eastman Dry Plate Company. The apparatus for coating the film base was patented by Eastman on March 22, 1892.[21] According to present records, the first supply of this stock to be used for producing successful motion pictures was sent to W. K. L. Dickson at the Edison Laboratories in July or August, 1889.[18, 22]

**1891.**—Eastman daylight-loading roll introduced.

**1895.**—In August, Eastman introduced the first positive motion picture stock; prior to this time motion pictures were made on negative film, which could be bought in 100-foot lengths. Many experimenters in Europe at this time bought the Eastman uncoated nitrocellulose film bare and coated it themselves, notably the Lumière brothers in France.

**1903.**—Eastman introduced film having a gelatin coating on the rear surface in order to counteract curling of the film; the process had been patented by him in 1890.

**1904.**—W. C. Parkin, in France, was granted a patent[23] on a method of making celluloid non-inflammable by adding a soluble metallic salt to ordinary celluloid. Subsequently, many others, chiefly in France, were granted patents on various ways of rendering celluloid non-inflammable or slow-burning, by means of adding various metallic salts.[24]

**1913.**—In September, Eastman introduced panchromatic negative motion picture film.

**1919.**—Eastman, introduced for the first time film that had latent image footage numbers printed on its edge; the markings included also the date, which was later omitted, and the markings evolved into the form as used today. The system was patented by Joseph Aller in 1922, the application being made in 1917.

**1921.**—On March 1, Eastman introduced colored base positive raw stock in nine colors: orange, amber, light amber, yellow, pink, red, green, blue, lavender, in addition to clear (black and white). Prior to this time, colored stock had been made in the various finishing laboratories by dyeing the emulsion after the processing of the picture.

**1923.**—In January Eastman introduced the 16-mm. reversal film and apparatus for amateur use.

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# EARLY STAGES OF KINEMATOGRAPHY*

C. H. BOTHAMLEY

***Summary.***—*The author, who presided over the meeting of the Photographic Convention of the United Kingdom at Chester, England, in 1890, describes some of the work of E. J. Marey, Muybridge, Friese-Greene, and Le Prince, pioneers in the art of producing and exhibiting motion pictures. The information given in this paper is particularly interesting in view of the personal acquaintance of the author with these pioneers during the time in which they were conducting their work.*

When an invention or development in pure or applied science rapidly receives recognition and wide application, especially if it be of a kind that achieves popularity, there is always a chance that the merits of the pioneers responsible for the invention or development will be underestimated, and even that the precise part that they played will be forgotten. For example, though the name of E. J. Marey, Professor in the College of France, is occasionally mentioned, it is doubtful whether the importance of his work is fully appreciated, notwithstanding the fact that his book, *Le Mouvement,* was translated into English by Dr. Eric Prichard, and published in 1895. It is not improbable that this is due to the fact that Marey restricted himself to his original line of work, the study of the movements of living things, from the scientific rather than from a popular point of view, and his book is a somewhat technical account of his results, with illustrations that are numerous, but on a small scale.

Marey himself states that the real originator of this line of work was the famous astronomer, Janssen, who, in December, 1874, took a series of successive photographs of the transit of the planet Venus across the face of the sun. A rotating circular plate was used, the interval between successive exposures being seventy seconds. Janssen, moreover, suggested that this method of making successive photographs at regular intervals might be applied to the study of the motion of animals, especially of locomotion.

After Janssen, came Eadweard Muybridge who, about the year 1880, or a little earlier, at the suggestion of a Mr. Stanford, a former

* Reprinted from the *Photographic Red Book,* London (1931), p. 78.

Governor of California, applied the principle to the photographic study of the movements of the horse, and who subsequently extended his experiments to other animals and to human beings. As is well known, Muybridge's method was to use a long line of cameras, the lenses of which pointed across a defined track, along which the object moved, the successive exposures being made by permitting the moving body itself to operate a simple system of shutter releases. The method was cumbersome, being limited somewhat severely by the number of exposures possible, but the results were very striking and valuable. A selection of them can be seen in Muybridge's book in the Library of the Royal Photographic Society. Much new light was thrown on the mechanics of walking and other movements.

Muybridge was able to demonstrate his results by means of the projection lantern and, in 1889, gave lectures at Newcastle-on-Tyne and at other places in the north of England. Professor A. Smithells, F.R.S., then professor of chemistry in the Yorkshire College (now Leeds University), persuaded him to come to Leeds and give a demonstration of his results. I met Muybridge on that occasion, and was able to give him some help in setting up his lantern and other equipment. The plates carrying the successive images were fixed to a large glass disk, which rotated between the condenser and the lens, while an opaque disk with transparent slits in it rotated in the opposite direction. The results surprised as much as they delighted the large and somewhat critical audience before which they were shown. Perhaps the most striking of all the demonstrations was that of the wing motion of a large white bird (a cockatoo, I think). As the wing moved in the up-stroke, brilliantly lighted by sunshine, we saw most distinctly every plume of the wing turn on its base, so as to present only its edge in the direction of motion, and thus offer as little resistance to the air as possible. As the wing came down, each plume turned back so as to present its flat surface to the air and thus gain the maximum impulse. I well remember the murmur of astonishment and pleasure that went through the whole audience, and the persistent demands for the repetition of what was as beautiful a picture as I have ever seen on a screen.

Marey and Muybridge were early in communication, and in order to obtain simpler and more portable apparatus, Marey invented his "photographic" gun. This apparatus, it should be noted, required only one lens. It was built in the form of an ordinary sporting gun, but of course, with different relative dimensions of its parts, and was

used on the shoulder and sighted in the same way as a gun. At first, plates were used, which were attached to a disk of glass contained in a drum fixed to the gun just as a revolver barrel would be. The disk could be rotated by clockwork actuated by the gun-trigger. The exposure was first made; then the shutter closed, and the disk moved around and brought another plate into position. With this apparatus, the number of exposures possible was 12 per second, and the plates were necessarily very small. Soon, "a continuous film very slightly coated with gelatin and bromide of silver" was substituted for plates, the film being wound on bobbins, at the end of which were flat plates having perforations that were engaged by a peg in a metal plate in order to rotate the bobbin. Black paper attached to the ends of the film made filling and changing possible in daylight. The images obtained with this apparatus were 9 centimeters wide. The improved apparatus and the increased sensitivity of the films obtainable made it possible to study the movements of a wide variety of living beings, the results of which study are set out in the book to which I have already referred.

In a delightful place in Beaune, bounded on one side by one of the great bastions of the fortifications, and on the other by a row of those dignified renaissance houses that give a distinct cachet to this quaint old town, there is a railed-in enclosure planted with graceful trees; in their midst is a life-sized statue of Marey, a sturdy thick-set seated figure with a face of marked character. Against the figure is a mass of stone, on the body of which are carved representations of his pictures of horses; while, as a frieze, there is a representation of his study of a flying bird. A long inscription sets out the achievements and honors of this distinguished Professor of the College of France, and the esteem in which he was held by his townsmen and countrymen.

Friese-Greene, on June 26, 1890, at a meeting of the Photographic Convention of the United Kingdom at Chester, over which I presided as president for the year, read a paper on *A Magazine Camera and Lantern*. He exhibited and described the camera that he had invented for making a long series of successive exposures on a sensitive film, which was moved by means of perforations in the film itself, instead of by perforations on a bobbin. He likewise exhibited and described a lantern that he had devised for projecting the images so obtained. Unfortunately, on the journey from London, the projection apparatus had been damaged so that it could not be used, and

the films that Greene had brought with him for exhibition could not be projected. This accident and the non-descriptive title which he gave to his paper were most unfortunate, and I am inclined to doubt whether any of the numerous experienced photographers at the meeting quite realized what a distinct advance Greene had really made.

It is a point of interest that the art now so widely applied for purposes of entertainment originated from a desire for making scientific investigations, of which most of the patrons of the cinema are probably ignorant; although to a very limited extent it is occasionally brought to their notice that the methods used to produce the pictures that amuse them are still constantly employed in scientific studies of great importance from various points of view.

Le Prince, whose claims as one of the pioneers I have recently advanced, I knew well by sight; in fact, I met him once or twice at the house of Mr. and Mrs. Wilson, with whom he had gone abroad just before his mysterious disappearance. I have, however, no recollection of having heard anything about his work in kinematography up to the time when I left Leeds in August, 1891, although I was a fairly regular attendant at the meetings of the Leeds Photographic Society. Probably he did not desire publicity until he had made satisfactory arrangements for working his patents.

# BOOK REVIEW

**Making Better Movies.** A. L. Gale and R. C. Holslag. *Amateur Cinema League, Inc.*, New York, N. Y., 1932, 205 pp.; a limited edition for distribution to members of the League.

The purpose of the book is to unravel some of the mysteries that motion pictures seem to hold for many amateurs, particularly those who are new at the work, and to discuss the problems of "making better movies." For that reason, it is written in a rather elementary manner; and although the book might be of questionable value to professional motion picture engineers, it should be of interest to those engineers, at least, whose commercial activities bring them into contact with the amateur and the amateur market, so that they may be fully cognizant of the problems facing the purchasers and users of their equipment and material.

Necessarily, the book deals with 16-mm. film and equipment, a few allusions being made to the 8-mm. systems. The nature of the book can best be appreciated by considering its contents: Chapter 1 contains an introduction to the subject, instructions on how to handle the camera, a discussion of sizes of film, exposing, stop numbers, lighting, planning the picture, footage, *etc.* The second chapter deals with handling the projector, caring for the film, editing, making splices, and titles. The third chapter discusses lenses, artificial lighting, subjects for photographing; and the fourth chapter deals with fades, multiple exposures, irises, and dissolves. The last chapter explains the use of Kodacolor, animation, close-ups, and various other applications of motion pictures. Finally, a few pages are devoted to the purposes and aims of the Amateur Cinema League.

S. Harris

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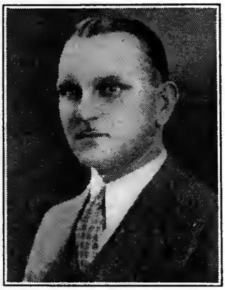

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# SOCIETY ANNOUNCEMENTS

## SPRING, 1933, CONVENTION

### HOTEL PENNSYLVANIA, NEW YORK, N. Y.
### APRIL 24 TO 28, INCLUSIVE

Arrangements for the approaching Spring, 1933, Convention, to be held at New York, April 24 to 28, with headquarters at the Hotel Pennsylvania, are rapidly proceeding, the plans including a number of outstanding presentations that will make it worth every one's while to be present at the meeting. Standardization is to play an important part in the proceedings. The economy trends in sound picture production and exhibition that the industry is now showing will be discussed.

The semi-annual banquet of the Society is to be held on April 26, at the Hotel Pennsylvania. An evening of pleasure and interest is promised, and all are urged to make every effort to attend.

Mr. W. C. Kunzmann, chairman of the Convention Committee, is being ably assisted in his efforts to make the Convention an outstanding success by the Local Arrangements Committee consisting of:

H. GRIFFIN, *Chairman*

| | |
|---|---|
| A. S. DICKINSON | S. HARRIS |
| P. H. EVANS | W. C. HUBBARD |
| J. FRANK, JR. | J. H. KURLANDER |
| O. M. GLUNT | H. RUBIN |

M. W. PALMER

All technical sessions will be held in the *Salle Moderne*, on the roof of the Hotel Pennsylvania. Registration will be opened at 9 A.M., Monday, April 24. The registration fee will be $3, and the banquet charge $4.50.

Plans are being made to assist out-of-town visitors to the Convention to pass an interesting time while in New York, and special film programs and trips of interest will be arranged. Full details of the program, including hotel rates and other pertinent information, will be mailed to the members of the Society at a later date. Members and friends of the Society are urged to make every effort to attend the Convention.

## EXHIBIT OF NEW MOTION PICTURE APPARATUS

### SPRING, 1933, CONVENTION

Arrangements are being made to hold an exhibit of newly developed motion picture apparatus, in order to acquaint the members of the Society with the newly devised tools of the industry. This exhibit will not be of the same nature as the usual trade exhibit. There will be no booths, although each exhibit will be allotted definite space, and all exhibits will be arranged in one large room. The following regulations will apply:

1. The apparatus to be exhibited should be new or have been developed or improved within the past 12 months.
2. Each exhibitor will be permitted to display a card giving the name of the manufacturing concern, and each piece of equipment shall be labeled with a plain label free from the name of the manufacturer.
3. A technical expert capable of explaining the features of the apparatus exhibited must be present during the period of the exhibition.
4. A charge for the exhibit will be made in accordance with the space occupied, as follows: up to 20 sq. ft., $10.00; 20 to 30 sq. ft., $15.00; 30 to 40 sq. ft., $20.00; 40 to 50 sq. ft., $25.00.

Please direct requests for space to the General Office of the Society, 33 West 42nd St., New York, N. Y., stating the number and nature of the items to be exhibited.

## PAPERS COMMITTEE

At a meeting held on January 27, at New York, plans were laid for the papers program of the approaching Convention, announced above. When the arrangements shall have been completed, copies of the final program will be mailed, together with other information concerning the convention, to all the members of the Society. The plans include symposiums on the economic trends in the production and exhibition of motion pictures and a number of demonstrations of remarkable interest. Among the later will be the presentation to the Society, by the Projection Practice Committee, of the test film described in *Society Announcements* in the February issue of the JOURNAL.

Mr. O. M. Glunt, chairman of the Papers Committee, also indicates that an interesting session will be devoted to the subject of producing special types of motion pictures, such as educational, industrial, animated cartoons, and the like. Considerable attention is being paid also to subjects of direct interest to exhibitors, and it is expected that papers dealing with these subjects will be presented by a group of men prominent in the field of exhibition.

## LAWRENCE C. PORTER

It was with the greatest reluctance that the Board of Governors, meeting on January 20, 1932, at the Hotel Sagamore, Rochester, N. Y., resolved to accept the resignation of Mr. Lawrence C. Porter, which had been tendered as a result of his entering fields of activity remote from the motion picture industry.

Mr. Porter was one of the charter members of the Society and served uninterruptedly in an official capacity from 1921 to date, alternating from Governor in 1921, President, 1922–23, Past President, 1924–25, Governor, 1926, Secretary, 1927–28, President, 1929, Past President, 1930–31, Governor, 1932 to date.

***Resolved:*** *That the Board of Governors record its deep appreciation of the many years of faithful and unselfish service to the Society rendered by Mr. Porter. Perhaps no other member has contributed so much as has Mr. Porter to the upbuilding of the Society, his efforts being a natural result of his unbounding energy, industry,*

*integrity, sound judgment, and charming personality. The loss of his services is deeply regretted by every member of the Board; it is a great loss to the Society.*

## STANDARDS COMMITTEE

At a meeting held at New York, N. Y., on February 3, the subject of standardizing on a single type of film perforation was discussed, in view of difficulties that seem to exist owing to the use of different perforations for positive and negative film. The Committee is proceeding to investigate the elements of the problem, and will report on them at the forthcoming convention, to whatever extent the intervening time permits.

Other matters include the compiling of a glossary of terms used in color cinematography, work on which is now proceeding under the efforts of the Color Committee, and the desirability of arriving at some form of standardization in the field of sensitometry were discussed.

A revision of the present booklet of standards is under way, which, when completed, will form a considerable part of the Committee's report. Other subjects on which the Committee is working concern the standardization of sprocket dimensions, variations in the width of reel hubs, and the possibility of standardizing the sizes of projection screens.

## SOUND COMMITTEE

On January 9, a meeting of this Committee, held at New York, was called for the purpose of organizing the work and outlining the plans for the report to be rendered at the Spring Convention.

Another meeting was held on January 31, at which time the subjects previously outlined were discussed in greater detail and the framework of the report constructed. Among the problems facing the Committee at the present time are those concerned with the introduction and use of the wider range of frequency and volume in recording and reproducing sound. Other subjects deal with the problems of film development and auditorium acoustics.

## MUSEUM COMMITTEE

The Museum Committee, under the chairmanship of Mr. E. Theisen, has been fortunate in having the active assistance of the personnel of the Los Angeles Museum during the past few months in improving and extending the S. M. P. E. exhibit at that museum. New accessions to the exhibit include memoirs of Vitagraph by J. Stuart Blackton, and an additional presentation by Mary Pickford and Douglas Fairbanks. The R. K. O. Studios have made for the exhibit a series of devices illustrating the methods of creating artificial rain, wind, railroad, and other noises to be synchronized with photographed pictures. There were obtained also a series of miniatures made by Willis O'Brien, who made *The Lost World*, and a collection of manuscripts written by Griffith, Sennett, Florence Lawrence, King Baggott, and about fifty others, dating from about 1902 to the present time. Some of these are only six scenes long, and bear itemized expense accounts of less than a hundred dollars recorded in pencil. Many small accessions have been received, too numerous to mention, and a considerable amount of material has been promised.

The chairman of the Committee is making available for the students of the University of Southern California such facilities as the exhibit may command in the way of furnishing information for theses and other research for their studies of motion picture appreciation. (This University is the first to raise the study of motion picture dramaturgy and technic to the academic rating, offering college credits for the courses.)

## PROJECTION SCREENS COMMITTEE

At a meeting held at New York, N. Y., on February 17, consideration was given to the desirability, and possibility, of standardizing the sizes of projection screens. Such standardization, the Committee felt, would eliminate a great deal of waste, both of time and material, for which the patron of the theater must eventually pay; would avoid errors in ordering screens; would expedite the shipment of screens when so ordered, and lead to lower costs.

It was the general opinion of the Committee that the sizes of screen should be specified in terms of the *size of the picture,* the specification referring only to the width of the picture because of the invariable relation (0.600 × 0.825) between the width and height; thus, a *No. 20* screen would refer to a *picture area* 20 feet wide and 14.5 feet high.

The Committee also considered the relation between the width of the screen and the distance of the front row of seats from the screen, as well as the maximum angle at which the screen should be viewed in order to avoid excessive foreshortening of the picture. In addition, plans were discussed for supplying, as part of the Committee's report, samples of paper chosen according to their reflectivities, which, when viewed against the screens by the exhibitor, would furnish an approximation to the reflectivity of his screen on choosing the paper sample that most nearly matched the screen in respect to brightness.

These subjects will be discussed in detail in the report of the Committee, to be presented at the Spring Meeting at New York, April 24 to 28.

## COMMITTEE ON SCREEN BRIGHTNESS

This Committee consists of representatives of the several projection committees, who have been meeting recently for the purpose of looking more carefully, and from all points of view, into the problem of determining what screen characteristics are found in the field, and what recommendations to the field might be advisable, both in respect to the screen brightness itself and to methods of measuring it. The Committee consists of Mr. S. K. Wolf, chairman of the Projection Screens Committee; Prof. A. C. Hardy, chairman of the Projection Theory Committee; Mr. H. Rubin, chairman of the Projection Practice Committee; and Mr. W. F. Little; who have been assisted at their meetings by Mr. McCandless, of the Illuminating Engineering Society.

## SUB-COMMITTEE ON EXCHANGE PRACTICE

At a meeting held on February 15 at the General Office of the Society, the final form of the report of the sub-committee, published in this issue of the JOURNAL, was determined. In addition, plans were laid for the more detailed examination

of some of the subjects mentioned in the report, with the view of arriving at definite recommendations for the conduct of exchange work that might form the basis of subsequent reports. The present agenda call for a study of film seasoning, the character of damage done to film outside the exchanges, splicing of film, and dimensions of reels.

## NEW YORK SECTION

Instead of holding the usual form of meeting this month, the members of the New York Section were given the opportunity of inspecting the new installations at the Radio City Music Hall on the morning of February 12. The tour through the building was led by Mr. R. Cox, of the sound department of RKO Theaters, who briefly described the equipment of the projection rooms and the general stage and theater equipment, including the lifts, the lighting, *etc.* The tour covered the entire theater, the lounges, lobbies, cafeteria, *etc.* Thanks are due the RKO management for the privilege accorded the members of the Section.

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## HONOR ROLL
### OF THE
## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

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## PAMPHLETS, BOOKLETS, AND CATALOGUES RECEIVED

*Copies of the publications listed here may be obtained free of charge by addressing a request to the manufacturer named. Manufacturers are requested to send new publications to the General Office of the Society immediately upon issue.*

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**Bell & Howell Co.:** Bulletin describing a new Character Title Writer, to be used with Filmo Cameras; the unit can be used for making movable-letter animated titles, the Title Writer being used vertically so that it is not necessary to fasten the letters to the card. For ordinary titles showing the hand as it writes, the unit is set up horizontally or at an angle to the table-top. Two 100-watt, 115-volt lamps are used, the lamps being silvered on one side so as to avoid the need of reflectors. They are mounted on joint and swivel supports so as to permit their proper adjustment for avoiding reflection into the camera from glossy subjects and to permit shadow effects to be obtained. Address: 1801 Larchmont Ave., Chicago, Ill.

**Du Pont Film Mfg. Corp.:** Bulletin *NF-2*, describing du Pont *dupac* negative. This is a bi-pack combination of two special negatives to be used in standard cameras, for making two-color separation negatives. Only a moderate initial outlay is necessary for making the necessary camera changes and special magazine equipment. It is stated that the means employed in the front negative for filtering the light make it possible to retain the full working speed and contrast of the front film emulsion, and at the same time to filter accurately and uniformly the light passing through to the rear negative. It is also said to be possible to hypersensitize the negative and to process it without contaminating the solutions with dyes. Address: Parlin, N. J.

**The Educational Screen, Inc.:** A booklet entitled *1000 and One, The Blue Book of Non-Theatrical Films.* A classified list of the films obtainable in a great many subjects. Full information is given concerning the title, number of reels, nature of the subject, and distributor, for 16-mm. silent, 16-mm. sound-on-disk, 35-mm. silent, and 35-mm. sound-on-film or disk. The subjects embrace most phases of science, sociology, government, health and hygiene, industry and engineering, literature and drama, psychology, war—naval and military. Religion, comedy, and travel subjects are included. Address: 64 E. Lake St., Chicago, Ill.

**General Radio Co.:** Catalogue *G*, lists and describes the construction and uses of electrical measuring apparatus and accessories such as resistance devices, condensers, inductors, frequency and time measuring devices, oscillators and amplifiers, bridges, generators, instruments for measuring modulation and distortion, oscillographs, *etc.* Address: Cambridge A, Mass.

**General Radio Co.:** *The General Radio Experimenter*, Vol. vii, No. 7, describes the principles and applications of the stroboscope in studying the motions of objects; the elementary mathematical theory of the stroboscope is also presented briefly. The Edgerton Stroboscope (type *548-A*) employs a high-intensity

mercury arc, the flash of which has a duration of only five microseconds, during which interval an object moving at the rate of a mile a minute traverses a distance of only five-thousandths of an inch. Fundamental synchronism can be achieved at rotational speeds up to 10,000 r.p.m. Address: Cambridge A, Mass.

**Globe Automatic Sprinkler Co.:** Bulletins describing the model *C* Dry Pipe valve and the *Saveall Airomatic* Sprinkler System. Details are given of the construction and design features of the equipment, and the manner of making the installations. The *Saveall* Sprinkler System is designed particularly for installations where the supply of water is limited and where the Standard Automatic sprinkler systems may not be used economically. Address: 2035 Washington Ave., Philadelphia, Pa.

**Jenkins & Adair, Inc.:** Circular describing the *Phonopticon* and *Controlophone.* These are sound-on-disk reproducing devices, for which special disks are prepared having recorded on them sub-audible (50 cycle) notes, lasting but a brief interval and recorded at selected points in the sequence or scenario. The 50-cycle note, upon actuating the pick-up, is diverted from the reproducing amplifier by means of a selective filter, and is made to operate a relay. In the *Phonopticon* the relay is made to open and close the circuits of a motor driven mechanism for changing lantern slides at the instants when the 50-cycle notes occur on the disk. The *Controlophone* is a special adaptation of such a system for sales promotional and educational purposes. Both types of instruments are mounted in suitable cabinets, and may be used for presenting lectures, travelogues, sales talks, *etc.* Address: 3333 Belmont Ave., Chicago, Ill.

**RCA Victor Co.:** A booklet describing the new RCA Victor sound recording system having the features of increased dynamic range, increased frequency range, and decreased ground noise. The applications of the system to the needs of motion picture theaters are described, and a general description of the principles of the system is presented. The various design and construction features of the component parts of the equipment are described in detail.

**Victor Animatograph Corp.:** This circular announces a new 500-watt Mazda lamp, produced by the General Electric National Lamp Works, which is suitable for use in the Victor Model *10FH* Premier Hi-Power 16-mm. projector. Although this projector, having a built-in lamp resistor in the base, is ordinarily supplied with the 400-watt lamp, it will accommodate the new lamp without alterations of any kind. The 500-watt lamp is supplied only when so specified. It operates at 100 volts, and should not be confused with the older *T12* 500-watt, 110–120-volt lamp. The new lamp employs an 8-coil biplanar filament, and provides greater illumination. Address: Davenport, Iowa.

# JOURNAL

### OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

**Volume XX** **APRIL, 1933** **Number 4**

*CONTENTS*

# JOURNAL
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SYLVAN HARRIS, EDITOR



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Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

# COMPOSITE PHOTOGRAPHIC PROCESSES*

H. D. HINELINE**

**Summary.**—*The author traces in this paper the development of composite photographic processes, in terms of the patent history of the art, from its beginning to April 1, 1932. For convenience, the art is divided into three phases, namely: the mask process, the projection process, and the color-separation process. Each of these lines has evolved into several variants, the development of which is traced through the patent literature.*

Composite photography may be described as the process of making pictures in which the background and the foreground are obtained from separate sources, and combined to produce the completed picture. To obtain a satisfactory combination, some means must obviously be provided to prevent overlapping of the respective picture-element images. Various means have been proposed and described chronologically in various United States patents, which form the original sources of material for the following description of the suggested processes.

The patent literature describes three kinds of processes, which differ broadly in their various details. The earliest process in point of time may be called the mask process; the next may be called the projection process; and the third may be called the color-separation process. The mask process has developed along several lines, yielding a number of variants that differ considerably among themselves, although all utilize some kind of opaque mask or shield for separating the components of the picture and for avoiding such difficulties as overlapping, "ride," ghosting, and fringing. Also, certain of the suggested processes utilize elements of all three of the processes as hereinafter differentiated.

As is usual in commercial photographic work, comparatively little information has been published, either in the technical or popular

* Received March 7, 1932.

** Patent Solicitor, New York, N. Y.

journals, bearing on these composite processes, and the most detailed information seems to be found in the patented art.

### MASK PROCESSES

The first patent publication of a composite photographic process was patent No. 149,724, issued on April 14, 1874, to C. M. Coolidge. This patent describes, of course, only a still photographic process, as it was issued long before the days of motion pictures. But the principle of holding a card, screen, or mask, carrying the desired foreground matter, in front of undesired parts of the subject in order to achieve a cartoon effect, is the forerunner of many of the later processes, and carries the germ of the idea from which the later-developed mask, screen, and cartoon processes grew.

During the twenty years following the issuance of this patent, the foundation was laid for all the other types of composite processes, as will later be described; the patents that were published related, mostly, or at first, to still photography only, later branching out into the motion picture art soon after the advent of the screen. For some reason effort seems to have been concentrated for a time on the processes other than the mask process, with the result that we do not find another patent for a screen or mask process until October 19, 1915, when patent No. 1,156,896 was issued to J. E. Garrette. Nevertheless, much more work seems to have been done on the mask and screen processes than on all the other processes, if one may judge by the number of patents that were issued.

The Garrette patent describes the use of a combination of colored lantern-slide and motion picture film for simultaneous projection, the slide having a portion prepared to be occupied by the small field of the moving picture. The stationary slide thus becomes, in effect, a screen or mask coöperating with the motion picture, and is claimed so to act in the patent, which also contains claims referring to the projector. The patent has, however, expired.

The first mention of the device that may be called a traveling mask is found in patent No. 1,226,135, issued on May 15, 1917, to R. V. Stambaugh. In this patent is disclosed a motion picture negative, which may be a cartoon if desired, having a clear space in each frame. This negative, which may be regarded as the traveling mask, is placed in the camera together with an unexposed film, the camera then being trained on a card bearing the matter to be added to the first negative. The light from the white portions of the card prints the

negative, while the lettering or other matter on the card is photographed directly on the unexposed film through the clear portion of the negative. The object of the process is to produce a number of advertising films, respectively carrying the names of different advertisers, and different copy, but using only a single negative of the action or cartoon. The process is aimed at reducing the cost of advertising films. It may be of interest to note that while the patent monopoly has yet to remain in force about two more years, the claims are very restricted, being limited to the process of combination printing of a negative and photographing of other matter. As this is the actual invention, the claims are properly limited to such a scope.

The next patent, chronologically, applies the idea of the Coolidge patent to the making of animated cartoons. This is patent No. 1,261,648, issued April 2, 1918, to P. H. Terry. It teaches a method of making animated cartoons by sketching the stationary parts of the picture upon a card that is blackened where the action or figures are to be, the figures and action being sketched upon another series of cards, blackened where the background is to be. Each frame of the film is then made by a double exposure, using the background sketch and the action mask for one exposure, and the action sketch and background mask for the other exposure. The claims are based on the superposition of successive exposures, and accordingly are rather limited in scope.

The first mention of a fixed mask used inside the camera is found in patent No. 1,269,061, issued June 11, 1918, to Norman Dawn. In the process disclosed photographs are made of the foreground and action behind a vignette or screen placed inside the camera so as to leave the top and background portions of each frame unexposed. The background is then added by photographing a card or drawing of the desired scene, the foreground of which has been rendered nonactinic. The claims are few and narrow in scope.

The complete disclosure of the process using a traveling mask as now known is first found in patent No. 1,273,435, issued July 23, 1918, to F. D. Williams. In this process, the action is photographed against a black background, yielding a negative that is transparent except for the action. A print of this negative is then made in such a way that the area of the action is left transparent, the background area being made opaque and as dense as possible by intensification. The print thus produced is the first mask. A print is then made

from this mask, producing the second or reverse mask. The action negative and the first mask are placed over the raw film and printed; then the background negative and the second mask are substituted and the raw film is printed again. The first exposure of the action is protected by the mask, the area of the background being protected from fogging by the first mask during the first printing. The disclosure suggests also that the first and second printing may be both of action, as a duplication of a single actor. The claims of the patent are rather broadly drawn to the double masking features of the invention.

A very poorly prepared patent, No. 1,279,099, issued September 17, 1918, to C. A. Gilbert, attempts to describe a process of combining with a drawn background a photographed silhouette of the action, and makes such claims; but the description is more suggestive than detailed, as most of the photographic steps, which seem to be important, are left to the imagination of the reader.

An interesting, but perhaps somewhat impracticable variant, which suggests but probably is not quite a traveling mask, is found in patent No. 1,296,471, issued March 4, 1919, to L. S. Brainerd. The system disclosed consists of a camera, in front of which is positioned a guide and a means for producing intermittent motion of a member carrying a series of sketches forming the successive views of an animated cartoon. Beyond the strip, in the same field of view, there is also provided a stage for action by ordinary actors. The actors on the stage and the cartoon on the strip are then combined on a single film; but it does not affirmatively appear that the cartoon strip is transparent, as would be necessary for a real traveling mask. The claims are narrowly drawn to the combination of cartoon and action.

The double mask system of the Williams patent is extended to animated cartoons, made from life, in patent No. 1,355,648, issued October 12, 1920, to L. E. Brownley. The complementary masks are, however, made manually rather than photographically, so as to permit the desired modification of the outlines of the characters. The claims are, of course, restricted in scope by the previous appearance of the Williams patent.

A better disclosure of a process for making cartoons by using a double set of traveling masks is found in patent No. 1,375,918, issued April 26, 1921, to C. F. Lederer. In this patent the process described requires that silhouettes corresponding to the outlines of the action

or foreground matter, as well as drawings of the action, be made manually. A single drawing of the background is then photographed through the appropriate mask, and the successive drawings of the action are photographed on the same film and frame through the other mask. The patent contains a considerable number of claims, not very broad, but covering the invention well.

Movement of a simple mask crosswise within the camera is disclosed in patent No. 1,397,602, issued to W. O. Owen, on November 22, 1921. This seems to be a minor matter, but the issue of the patent may be noted.

An interesting variant of the fixed mask idea is seen in patent No. 1,464,054, issued on August 7, 1923, to F. D. Williams. The desired negative of the action is printed on the positive stock, in a camera which is used as a printer and which takes both the negative and the raw film stock, by light reflected through the camera lens from a card, the reflective power of which is modified so that light is reflected only to the parts of the negative film to be printed. Supplementary cards may be used to produce a composite, or double, exposure so as to combine separately photographed foreground and background.

Another patent, disclosing a process of somewhat doubtful utility is No. 1,476,885, issued December 11, 1923, to D. W. Griffith, in which a screen having an opening is used as an intermediate ground, with the foreground action in front, and the opening closed. After photographing the action the film is run back in the camera, the screen opening is cleared, and a sketch behind the opening is illuminated and photographed. The reason for the sequential, rather than simultaneous, photographing of the two does not appear.

An interesting but somewhat doubtful variation of the traveling mask method is disclosed in patent No. 1,503,731, issued August 5, 1924, to J. B. Walker. In this system two simultaneous negative exposures of the foreground and action are made; one of these is developed and used to make a printing strip for relief type; ink or dye is applied to the other negative exposure, as yet undeveloped, to protect the foreground while the background exposure is being added. Questions may be raised as regards the shrinkage of the film and the registration.

Patent No. 1,508,509, issued September 16, 1924, to L. F. Douglass, contains some interesting claims relating to the use of supplementary masks in the printer for combining foreground and background.

A similar structure in the taking camera is shown in patent No. 1,543,065, issued June 23, 1925, also to L. F. Douglass.

A convenient method of making complicated masks to be used in the camera is shown in patent No. 1,572,315, issued February 9, 1926, to E. Scholl. In this method a metal strip is coated with emulsion, the desired background scene is photographed on the strip, the desired solid portions being protected by resist and the etching being done through the desired openings.

Still another variant of the early Coolidge patent is described in patent No. 1,574,464, issued February 23, 1926, to J. Bartholowsky, disclosing a photographic system in which a miniature model of part of the background is placed near the camera, while other portions of the desired scene, of full size and visible through openings in the miniature, are placed farther away. The claims seem to be limited to the use of a miniature above a reference level.

Stationary supplemental masks placed outside the camera are disclosed in patent No. 1,576,854, issued March 16, 1926, to J. F. Seitz. These masks are used with a rigid frame and track which holds the camera and mask in fixed alignment. The masks are made by projecting a photograph from and in the same camera. This patent has been reissued as No. *Re* 17,125.

Patent No. 1,589,731, issued June 22, 1926, to F. D. Williams, makes a somewhat uncertain attempt at disclosing a composite process in which the action and lower portion of the background are photographed, printed, and projected to a screen, a sketch of the remainder of the background being made on the screen which is then photographed and combined with the foreground and action in ways not clearly described. This patent also has been reissued, as No. *Re* 17,330.

In using traveling mask processes, the most serious technical problem is that of registering the mask accurately with the various negatives and the print film, in view of the differences of shrinkage among the various films. The first disclosure of means designed to avoid this difficulty appears in patent No. 1,610,410, issued December 14, 1926, to F. F. Baker. Arrangements are made for splitting the light so as to be able to expose the action negative and the mask film simultaneously, and suitable means are provided in processing for equalizing the shrinkage. The mask film is then used in photographing the background. The developed foreground and background negatives are then cemented together, and printed in an optical printer.

Patent No. 1,616,237, issued February 1, 1927, to J. F. Seitz, is a companion patent to the previously mentioned patent No. 1,576,854. Minor modifications of the system are described, in which an enlargement is used as a mask, part of the enlargement being cut away so as to permit the use of ordinary stage and actors at a greater distance.

An excellent description of the traveling mask process, and its application to the two-color subtractive process known as "Technicolor," is given in patent No. 1,641,566, issued September 6, 1927, to J. A. Ball. The claims are directed toward two-color compositing, but the description shows the features involved in obtaining register in the traveling mask process, and also means for obtaining color balance in the composite film. In the process as described the foreground and background are combined by processing the color-separation silver print images in combination with the masks, before the color printing is done, compositing being done separately for each color.

The extent to which masks may be used outside the camera is shown in patent No. 1,669,963, issued May 15, 1928, to P. W. Youngblood. The process requires an enlargement of the desired background scene, with a part cut out where the action is to occur. The cut-out opening is then backed by a larger or full-scale enlargement, at a greater distance from the camera, the actors performing in the space between the two enlargements. The patent has only a single, very narrow claim.

An interesting means of obtaining the traveling mask is shown in patent No. 1,697,315, issued January 1, 1929, to M. Handschiegl. The foreground exposure is made upon a film that is not color-sensitive, before a non-actinic screen. The film is then developed, rinsed, and dried without being fixed, and the mask is made on panchromatic film by exposing it to light to which the first film is not sensitive, such as red light. The background exposure may then be added to the first film, using the mask to protect the foreground exposure. The film is then developed a second time, fixed, *etc.*, yielding the desired composite negative.

A traveling mask substitute is suggested by N. Osann in patent No. 1,698,448, issued January 8, 1929. The exposure of the foreground is made against a non-actinic field, and developed. Then, without fixing it, the developed image is toned, to render it opaque; and the dried film is reëxposed to the desired background; it is again

developed, fixed, *etc.*, after which it is printed. Although this process avoids problems of registration, it substitutes those of obtaining tone balance, and introduces chemical and grain difficulties.

An elaborate description of a simple double exposure process is found in patent No. 1,737,021, issued November 26, 1929, to G. B. Pollock. A test portion of the original partly exposed action film is used with a chart board to aid in preparing a sketch of the substitute background. It does not appear that by this process a whole new background will be supplied, but that only a portion of the background, separated from the action, will be replaced.

An odd suggestion is made in patent No. 1,771,029, issued July 22, 1930, to J. Burkhardt. Successive frames carry the action and the background alternately, the background frames having opaque portions corresponding to the action as shown in the adjacent frames. The adjacent frames are then projected together, for the effect of relief, seemingly a pseudo-stereoscopic effect. A modification in which the frames are placed side by side, instead of in sequence, is shown in patent No. 1,785,336, issued December 16, 1930, and yet another in patent No. 1,801,656, issued April 21, 1931.

R. J. Pomeroy discloses, in patent No. 1,818,354, issued August 11, 1931, the use of a half-silvered mirror and two cameras, one camera making the action negative, and the other making the mask, using a fuller exposure on very contrasty working stock. The mask film is then developed, *etc.*, and used as a protection for the action exposure on the other film during the exposure of the background.

A process in which some of the steps of the animated cartoon processes are used is shown by O. Chouinard, in patent No. 1,827,282, issued October 13, 1931. In this process two similar negatives are made simultaneously in separate cameras. One negative is developed and projected on a screen on which the background is then drawn, a non-actinic area being left where the foreground appears. The frames of the other film, exposed to the action, are then reexposed one by one to the drawing, so as to add the desired background, the necessary changes in the non-actinic area of the drawing being made between frames according to the changes in position of the action.

What seems to be a worth-while detail in the process of making the traveling mask is shown in patent No. 1,840,669, issued January 12, 1932, to M. Handschiegl. This patent describes the use of two super-

posed films in the camera, both films being exposed to the action. One, preferably the rear one, is developed for contrast, and is then positioned in front of the other, still undeveloped, so as to protect the exposure of the action during the exposure of the background.

A companion patent, No. 1,840,670, issued to the same inventor and on the same date, gives a terse summary of the traveling mask processes, and seeks to claim a process in which a positive print of the desired background is used with the mask, necessitating only one mask. The claims, however, seem narrow, and of doubtful validity.

The mask and screen processes described above are designed with the idea of photographing the foreground and the background separately, and of obscuring complementary areas of the film during one or both exposures by means of an opaque mask, or shield, this being the essential element, whereby the composited element is fitted into the opening of the other exposure made by the shield.

### PROJECTION PROCESSES

It has, of course, long been known that stage settings could advantageously be reproduced from full-size drawings, and it seems to have been early appreciated that a stage background could be produced by optically projecting a small transparency, such as a lantern slide, on a translucent screen serving as a back drop, as is shown in patent No. 486,606, issued to F. Seymour on November 22, 1892. This patent shows a stage setting consisting of a translucent screen upon which the scene is projected by a stereopticon, the actor being positioned in front of the screen. Photographing of the stage and action is not, however, suggested in this patent.

The first suggestion of composite photography, for a still picture, by directly photographing a normal figure or foreground against a projected background, is found in patent No. 656,769, issued August 28, 1900, to R. M. Hunter. However, this patent involves photographing separately the foreground or figure, and the background, probably because of differences in illumination, and the difference in exposure time for the two. It was, of course, possible to do this in still photography, where the subject could stand still long enough to become the necessary silhouette before the projected background.

The process of simultaneously exposing the foreground and the background by projection, in still photography, is disclosed in patent No. 1,053,887, issued February 18, 1913, to H. Sontag. This patent also describes the use of a non-actinic front surface on the translucent

screen, for reducing the effect of front light in degrading the contrast of the projected background.

A variant, in which the projection screen covers part of the subject, is shown in patent No. 1,133,311, issued March 30, 1915, to W. W. Newcomb, also for still photography. This patent shows front projection, and photographic exposure from the front. (The projected matter is described as pictures of women's clothing. The subject would stand behind the screen, her head showing above it, and be photographed to show how she would appear in her new clothes.)

What may be considered to be an off-shoot from the direct line of development of projection processes is found in patent No. 1,263,355. issued April 16, 1918, to P. Artigue. This patent describes a process for making animated shadowgraphs, in which the background scene is sketched on a translucent screen illuminated from the rear by a point source of light, the desired shadows being thrown upon it by the actors, to be photographed together with the background.

The first suggestion of simultaneous projection and photographing for motion picture work is found in patent No. 1,270,778, issued July 2, 1918, to A. D. Brixey. This patent discloses means for adding dialog inscriptions to a motion picture film (before the advent of sound) by projecting the successive frames upon a translucent screen before the camera, and holding up to the screen a card inscribed with appropriate lettering and provided with a "leader" that would follow the mouth of the character supposed to be speaking. The screen and card are then photographed to produce the desired film.

Still another off-shoot process is disclosed in patent No. 1,278,117, issued September 10, 1918, to J. S. Dawley, describing a process in which the background is inserted into the picture by reflection from a plate of glass in the line of sight of the lens, the actors being in the direct line. The way in which ghosting is avoided is not given, and this lack may be fatal to the process. It is doubtful whether this should really be considered as a projection process.

Another forward step is shown in patent No. 1,301,538, issued to L. S. Brainerd, on April 22, 1919. A coupled projector and camera operate in synchronism. The camera and the projector are placed side by side before a stage, which has an opaque screen at the rear. The background is projected upon the screen and actors together, no provision being made to prevent the projected image from being superposed on the actors. It may be noted that all the claims in

this patent are drawn with the phrase "cartoon pictures" for the projected material.

Attention may well be called again to the first of the Brainerd patents, No. 1,296,471, previously mentioned, as the claims in it may well be more pertinent to a projection process than to a mask process.

The third Brainerd patent, No. 1,307,846, issued June 24, 1919, carries the idea still farther by claiming the process, although the disclosure is much the same as that of the second Brainerd patent, No. 1,301,538.

It may be noted that at this stage, work on projection processes seems to have languished for a considerable time, nearly ten years, the Brainerd patents having been applied for in 1915, and the next issued patent appearing in 1925. This patent, No. 1,601,886, was issued on October 5, 1926, to E. Schüfftan, and discloses a camera, a partly silvered mirror in front of the camera lens, a screen on which the background is projected adjacent to one face of the mirror, and the stage setting and actors before the other side of the mirror, the two being composited by reflection and direct vision through adjacent reflecting and transmitting areas of the mirror. A synchronizing drive connection between the camera and the projector is well shown. All the claims seem to be limited by the inclusion of the partly silvered mirror.

A very nearly similar system is disclosed in another Schufftan patent, No. 1,690,039, issued October 30, 1928. These patents must be examined in the original, to see the minutiae of detail, and the differences in the respective disclosures, and claims.

The projection idea is applied to the manufacture of animated cartoons in patent No. 1,760,156, issued May 27, 1930, to N. H. Mann. The principal function of the projection, however, is to produce photoprints from the motion negative, from which photoprints cut-outs are applied to the successive cartoon card sketches.

The last patent to be mentioned in the field of projection compositing is No. 1,827,924, issued October 20, 1931, to F. D. Williams, showing a number of details of value in projection processes, including the displacement of the projector sidewise from the normal line of the screen so as to avoid the "hot spot," the use of two projectors throwing different picture components upon the screen, the use of superposed films in the projector, double exposure of the camera film to successively projected images from the projector, *etc.*

The projection method of compositing is thus shown to have been

brought to a high stage of development, becoming convenient and flexible in application, and possessing substantially fewer difficulties than are inherent in the mask processes. The most serious objection to the process is said to be the loss of detail and definition in the background copied from the screen.

### COMPOSITING BY COLOR-SEPARATION METHODS

Another interesting process involves the differentiation between the foreground and the background by means of color combinations, the process, broadly stated, being that of using a positive transparency of one picture component, which is transparent to the foreground image but is printed on the film for the background image. This process has been largely developed by Dunning and Pomeroy, but a small amount of prior art is worth noticing.

The first item of this prior art is patent No. 858,162, issued June 25, 1907, to F. J. Dischner, which discloses a process in which a positive of the desired background is positioned in front of the negative material in the camera, and an illuminated back-screen used behind the subject. The light from the back-screen prints the background positive on the negative material, as a negative; while the foreground subject makes a silhouette against the back-screen, and prevents exposure over the foreground area. The positive and the lighted screen are then removed, and the foreground subject is lighted and photographed without change of position. Another patent, No. 967,025, issued August 9, 1910, to Leonard and Oldaker, shows a camera structure adapted to this process. Both are for still rather than motion picture photography.

The first appearance of the idea of employing color for the separation occurs in patent No. 1,613,163, issued January 4, 1927, to C. D. Dunning. This patent suggests that the original negative of the background be printed to a positive, which is then color toned and tinted, placed into the camera with panchromatic film stock, and the foreground subject photographed through it against a colored background. As far as can be judged, the idea is to make the positive uniformly transmissive to white light, but non-uniformly transmissive to colored light, thereby making possible the exposure by white light passing through it from the foreground subject, and the printing of the positive simultaneously by colored light *en silhouette* around it.

A much clearer disclosure is found in patent No. 1,673,019, issued

June 12, 1928, to R. J. Pomeroy. This patent describes the use in the camera structure of a dye positive of the desired background, with panchromatic negative stock; and a back curtain, placed before the camera and behind the action, of a color contrasting with the dye positive, the action being illuminated with light of the same color as the dye positive. The foreground light then passes through the positive unhindered, making the exposure; while the background light, *en silhouette,* prints the positive, making the background exposure. This patent appears to contain the broadest claims to the process.

The next patent in order is No. 1,686,987, issued October 9, 1928, also to R. J. Pomeroy, which shows a process for combining separately photographed action and background in a printer by the aid of colored lights. The action is photographed before a white screen, so as to be surrounded by an opaque mat. From this negative is made a dye positive, in which the action printed in, say, blue, is surrounded by a red field. This is combined with a light print of the background also dyed blue. The two are superposed on panchromatic stock in the printer, and printed by mixed red and blue light, thus producing the desired composite negative. The light blue background print has a negligible effect under the heavy blue foreground action, which is printed by the blue light, but the light blue print strongly contrasts with the red light through the silhouette around the action. This is as ingenious and interesting a process as is found in the art, because of the nice balance of elements; although it is far from the simplest to work, nor does it promise better results than other processes.

Still another variant is shown in patent No. 1,715,510, also issued to R. J. Pomeroy, on June 4, 1929. In this form, the action is photographed before a non-actinic background, the negative being toned blue, on a clear field. A blue-dye background-negative-transparency is positioned in the camera in front of a panchromatic film, the camera being trained on the action negative, which is illuminated with red light. The negative is front-lighted in blue, and the respective lights print the two negatives on the panchromatic film in the camera.

A nice outline of the color differentiation compositing process with improvements is found in patent No. 1,776,269, issued September 23, 1930, to R. J. Pomeroy, the improvement specifically disclosed being that of using a negative film of the background positive print, dyed in a color such as yellow, with the blue background positive

print, so as to counterbalance absorption, by the print, of light of the same color as the print.

The latest of the patents dealing with this process is No. 1,788,740, issued January 13, 1931, also to R. J. Pomeroy, disclosing an interesting procedure of using the color-separation method with a silver print for the background scene. The process employs a split light beam with color filters, complementary lights on action and back screen, and panchromatic film, the foreground and background exposures being made on opposite sides of the film. One light beam emanates from the action; the other is *en silhouette* around the action, and prints the silver positive on the reverse side of the film. This, of course, involves the problem of registration of the two beams on the opposite sides of the negative film.

### GLASS SHOTS

Another procedure, which has attained to a separate status in the field, is identified by the phrase "glass shot." In this process, in its customary form, the desired background is painted, in miniature, on a plate of glass which is placed near, and in front of, the camera. Part of the glass is left clear so that the action may be photographed through it. This process is strictly a variant of the stationary mask process, but having attained to a separate field, may be separately treated.

The first mention of a process suggesting this method occurs in patent No. 45,449, issued December 13, 1864, to Wm. Callcott. This patent discloses simply a stage illusion, in which successive glass plates, on which the desired scenery is painted with light-translucent paint, are successively illuminated, the rear ones being visible through the front ones. No photography seems to have been involved in the process.

The next suggestion of interest is found in patent No. 1,019,141, issued March 5, 1912, to A. Engelsmann. A glass plate serves to reflect light from depressed screens carrying moving pictures of the actors only, without the background. The glass is placed in front of a painted drop; a pseudo-stereoscopic appearance is effected, the motion picture actors being expected to give the impression of being in front of the drop.

An interesting use of a glass plate—not quite a "glass shot" as now understood—is shown in patent No. 1,235,871, issued August 7, 1917, to C. M. Aument. This patent discloses a cartoon process,

in which the permanent background is drawn on the glass, the moving figures being sketched on it in successive positions and guide sketches being used on the back of the glass to aid in making the main sketches, which are then photographed. Still another cartoon process employing a glass plate is disclosed in patent No. 1,263,355, issued April 16, 1918, to P. Artigue, previously mentioned. The desired background is sketched on a translucent screen, and the actors are silhouetted on the screen by a single rear light. This is not quite a "glass shot," although it has most of the elements of a glass shot.

Still another approach to the glass shot idea is found in patent No. 1,278,117, issued September 10, 1918, to J. S. Dawley. In this process, a glass screen in front of and near the camera has projected upon it the desired background scene, while the actors are on a screen stage of normal size, beyond the glass.

Another interesting suggestion is found in patent No. 1,296,471, issued March 4, 1919, to L. S. Brainerd, and previously mentioned. It is of interest in that it shows means for photographing both the actors and a miniature sketch with the same camera, on the same film.

The next pertinent patent to be issued was No. 1,372,811, to W. L. Hall, on March 29, 1921. This patent shows in elaborate detail the steps to be taken in matching the miniature on the glass, in tone and perspective, to the desired foreground by means of targets, charts, and tone scales, and gives a good outline of the whole procedure. The claims refer to the broad process, and to the details.

It may be noted that glass shots are made with the miniature of the background on a glass plate as a matter of convenience; however, it does not appear that this is the only possible way, since similar results may be attained with the miniature on an opaque sheet in which openings are cut for the line of sight to the action in full scale, or in the solid, with similar openings.

This method of working is disclosed in patent No. 1,476,885, issued December 11, 1923, to D. W. Griffith. Here is used a screen having a hole cut in it. The screen is appropriately painted, and an actor may work in front of it, while another screen and actors may be visible through the opening.

The "glass shot" idea is carried still farther in patent No. 1,540,213, issued June 2, 1925, to O. R. Hammeras. The system disclosed is stated to be an improvement over the Hall patent No. 1,372,811, which improvement seems to lie in the idea of building sets to a point

just above the heads of the actors, and completing the top of the set by a painted miniature on a glass plate. The claims seem to be drawn to the idea of marking the outlines of the fixed scenery on the glass plate and completing the miniature from such guide lines, thereafter photographing from and through the glass.

The equivalent of a glass shot, that is, a miniature drawn or constructed of opaque material, without the glass, is described in patent No. 1,574,464, issued February 23, 1926, to J. Bartholowsky. This patent shows a bottom portion of a set constructed full-scale for the actors; and a top portion, in miniature and much nearer the camera, with the joining margins aligned before the camera, the perspective of the miniature part of the set being adapted to its distance from the camera.

The details of "glass shots" are still further developed in patent No. 1,742,680, issued January 7, 1930, to P. Artigue. The main feature of the disclosure is the use of filter colors, or dyes, on the glass to modify the appearance of the scene behind the glass.

The last patent to be noticed on the subject of glass shots is No. 1,764,490, issued June 17, 1930, also to P. Artigue, the main point of interest relating to the mounting of the glass and miniature on a staging with the camera so as to permit the two to be moved about as for panoramic views, without disturbing the relation of the glass to the camera. In view of the many devices for movable cameras with all sorts of attachments, a question may be raised whether such a system as here disclosed involves invention.

### GLASS SHOTS BY REFLECTION

One worker in the field, Eugene Schüfftan, has concentrated on a variant of the "glass shot," in which is employed a glass plate, partly reflecting, partly transmitting, that seems to have been developed to a substantial degree of completion. In each instance he uses a glass plate that is partly silvered, but has unsilvered transparent portions. This glass is placed before the camera lens, the camera beam being divided so as to bring light upon the film from two subjects.

The first of his patents, No. 1,569,789, issued January 12, 1926, discloses a mirror partly silvered over an area of the camera field of view in which the action is to occur, and unsilvered over an area of the field of view in which a miniature set is to appear. The action is then viewed by reflection, and the miniature set is viewed by transmission through the glass. The reverse procedure is, of course,

possible. Various details are outlined, such as an adjustable segmental mirror, *etc.*

His second patent, No. 1,601,886, issued October 5, 1926, deals mainly with the mechanical equipment for the process. It includes such items as a small projected background, a supplemental collecting lens to correct the focus on the miniature, mechanical details of the camera and miniature, *etc.*

Two other patents, Nos. 1,606,482–3, issued on November 9, 1926, furnish still other details of the process and apparatus, including the method of operating it, of preparing the mirror and the miniature drawing, registration, blending, *etc.*

Another patent, No. 1,613,201, issued January 4, 1927, discloses a special double-lens camera, which is combined with a considerable number of partly silvered mirrors for assembling a plurality of separate picture elements. This idea is extended in a somewhat better mechanical form in patent No. 1,627,295, issued May 3, 1927.

Still another of this group of patents, No. 1,636,112, issued July 19, 1927, shows and claims the details of a large collecting lens in combination with the mirror, for modifying the effective focus of the camera lens on the reflected image, bringing both reflected and transmitted light beams to an equally sharp focus.

The last of this group of patents to be considered is No. 1,690,039, issued October 30, 1928. This is a division of an earlier application, issued as patent No. 1,569,789, and discloses and claims the projection of a miniature upon a translucent screen, in combination with the partly silvered mirror, camera, and full-scale scenery and actors.

### SELF-MASKING PROCESSES

In any composite process the most troublesome problem is that of accurately registering the respective composited parts, the problem being most acute in traveling mask processes, and least acute in the color-separation processes. Because of the convenience of mask processes, attempts have been made to develop what may be called a "self-masking" process.

The first of these, as previously mentioned, is shown in patent No. 1,503,731, issued to J. B. Walker, on August 5, 1924. Walker proposes to swell the gelatin film so as to obtain a relief image of the foreground or action exposure, after development, but before fixing. A coat of ink or dye is then applied to the raised portions (the action may be photographed before a non-actinic screen for background).

The film is then dried, reëxposed on the other component, redeveloped, *etc.*, and the ink removed. Obviously, success depends upon inking only the foreground, and all of it.

The next similar suggestion is found in Patent No. 1,697,315, issued January 1, 1929, to M. Handschiegl. This patent proposes a process of photographing action on film that is not color-sensitive, developing, and printing the unfixed film on panchromatic stock by red light. A second print, made from this print, forms a mask to protect the first exposure while a second is added, after which a second development, *etc.*, yields the composite negative. This is not quite a self-masking process, but is of interest for the double development.

M. Osann suggests, in Patent No. 1,698,448, January 8, 1929, toning a developed but unfixed film of the foreground, photographed before a non-actinic screen, to increase the opacity of the image. He uses a cupric ferrocyanide toner for the more light absorbent red image. A second exposure is made over the toned image, developed, *etc.*, for the background. Panchromatic print film with the negative is suggested, probably to avoid the density unbalance between the two images. A simpler way might be to tone the second image.

R. J. Pomeroy, in Patent No. 1,755,129, April 15, 1930, suggests a similar process, toning the first image with a quinone toner, reëxposing *etc.*, the toning being removed by the fixing bath. He also suggests a selective desensitization as by phenosafranine, to protect the first image area. He also suggests, in Patent No. 1,755,130, same date, a pigmented casein coating, applied to the film after foreground development. Bleaching then hardens both the film and casein coating over the image, the rest being removed, producing a self-mask, over which the second exposure is made, developed, *etc.*, and the casein coating removed by mild caustic.

This assortment of processes should provide one, at least, which is usable under any given circumstances, although each has its limitations. It should also be noted that most of the above-mentioned patents are still in force. For further information on the processes described, copies of the patents may be obtained from the Commissioner of Patents, Washington, D. C.

# THE OPTICAL-PHOTOGRAPHIC PRINCIPLES OF THE AGFACOLOR PROCESS*

F. WEIL

***Summary.***—*The physical and photographic properties of the lenticular screen process of producing motion pictures in color, as developed by Berthon, and later known under the name Keller-Dorian and commercialized in the 16-mm. field under the name Kodacolor, are briefly described. The author traces the development of the process from the earlier mosaic screen process, and after giving consideration to the technical problems involved, indicates that the situation obtaining at present may be regarded as one stage of a development leading up to the application of the lenticular screen process to the 35-mm. field as well as the 16-mm. field.*

Processes of making motion pictures in natural colors must satisfy at least the following principal requirements in order to be technically and practically successful:

(1) The photographic manipulation and apparatus must be simple.

(2) The process must provide sufficient color saturation and resolution; that is, the color elements must be small enough to be unobjectionable.

(3) It must be possible to make prints from an original exposure.

(4) The process must make efficient use of the available light, both in making camera exposures and in projecting the pictures on the screen.

It would be impossible, within a limited space, to mention all the processes that have been suggested and tested, or are still in the experimental stage, for producing colored motion pictures. A review of present methods is given by J. Eggert.[1]

This paper describes briefly the physical and photographic principles of the lenticular screen process as developed by the French optician, A. Berthon, in 1908. In 1913, Berthon and Keller-Dorian formed the "Société anonyme du film en couleur Keller-Dorian;" and, under the name of Keller-Dorian, this process is widely known. Out of this company, the "Société Cinechromatique" was formed in France, while Kodak took over the patents and commercially applied the lenticular screen process to 16-mm. film under the name

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* Translated from *Filmtechnik*, 8 (Sept. 3, 1932), p. 1.

of *Kodacolor*. Recently, Agfa has also produced a 16-mm. film based on the same principles, called *Agfacolor*.

Up to the present time, both companies have restricted themselves to the production of 16-mm. film only. The amateur usually takes his pictures outdoors, where he finds a large variety of colors and a wide range of light intensity; the lenses of amateur movie cameras have sufficient focal depth even at large apertures. Moreover, the lenticular screen process is so simple that only small and easily adaptable accessories are required in order to apply it to any existing camera. As to the photography, there is no difference between this process and the reversal process generally used in 16-mm. film technic. Therefore, the technical development of this field has not been retarded by unsolved problems of a satisfactory printing process. The 16-mm. picture is projected only to a limited size and brilliancy on the screen.

The fact, however, that this process is being applied only to 16-mm. film should not lead to the conclusion that it can not be applied to the 35-mm. standard motion picture film. The situation at present may be regarded as one stage of a development leading to the application of the lenticular screen process to the 35-mm. field as well.

In certain respects, the lenticular screen process in its photographic and optical principles is an extension of the mosaic screen process, long ago introduced into amateur photography. Indeed it might be regarded as a color screen process modified for motion picture purposes. Both the lenticular and mosaic screen processes are so-called additive processes; that is to say, the required colors are produced by blending three primary colors. A combination of red and green produces yellow; red and blue produce purple; blue and green produce bluish green. Red, blue, and green when properly combined, produce white. Conversely, it is possible to analyze any given color, with respect to the proportion of red, green or blue contained in it, simply by using filters of these colors. The color may then be reproduced by mixing light of these colors in the same proportions. This separation, or analysis, of the color can be accomplished photographically by exposing the film to the object through the color filters, either simultaneously or in succession, using one or several lenses. For reproduction, these exposures must be optically superimposed in perfect registration. With a color screen or lenticular screen, however, the tri-color analysis can be made in a single ex-

posure, by dividing the photographic coating, in one way or another, into numerous small units, each unit being fitted with a red, green, and blue filter. The smaller the units, the higher the resolving power. Theoretically, these units should not be so large as to come within the resolving power of the eye (visual angle of 1 minute, corresponding to about 0.02 mm. at the natural viewing distance). Each area is fitted with a composite tri-colored window through which the light from each individual area of the object passes to the emulsion coating.

In the mosaic screen process we find the simplest application of this principle. Between the emulsion coating and the film (or glass), we find the color screen, an even blending of red, green, and blue transparent grains of starch or bakelite, irregularly dispersed. The mixture of the grains is never quite uniform, as the formation of small clumps of grains can not be avoided. The exposure of the emulsion is always made through the screen. Each group of differently colored grains forms a screen unit, in the sense already explained, and the light rays, passing through the grains, produce a photographic effect according to the primary-color content of the rays. In order to see the original in its true colors, it is necessary to subject the developed film to a reversal process, because the usual negative development produces only the complementary colors.

Unfortunately, the mosaic process can not be used for motion pictures. First of all, the enlargement necessary for motion pictures would magnify the grains of the color screen to a size within the resolving power of the eye, thus making the individual grains visible. Furthermore, on account of the random distribution of the color grains, local aggregations of similarly colored grains can not be avoided. A greater difficulty, however, is the fact that the random distribution of the screen elements over the entire image surface—their positions relative to the perforations of the film—changes with each and every frame of the film. On account of the intermittency of projection, these two effects cause a violent irregular movement of the colored grains, producing a disturbing visible effect particularly on larger areas of uniform color.

In order to adapt the color screen process to motion pictures, it would be necessary to arrange the color elements in a regular pattern parallel to the edges of the film. Thus the elements would no longer be distributed haphazardly. Naturally, the manufacture of such an extremely fine screen involves many practical difficulties;

nevertheless, commercial experimentation has already been successful and is being continued.[2]

The lenticular screen process as developed by Berthon solved the problem by very simple and ingenious means. Berthon abandoned from the very beginning the idea of attaching the filters, corresponding to the different surface elements, to the film, and of providing the film itself with a real color screen. On the contrary, the screen is produced on the film optically during the exposure, and on the screen during projection. The film serves only as a support for an optical system of tiny cylindrical lenses embossed on the film base. The width of each lens is about 0.028 to 0.043 mm., the focal length being 0.1 to 0.14 mm. The lenticular screen is adjusted to the taking or projecting lens system, as shown in Fig. 1. A color filter having three colored areas—red, green, and blue—in three parallel sections, is placed either inside or outside the lens system. It does not matter where the filter is placed, so long as it controls the aperture. Furthermore, the filter diaphragm, or its virtual image, must not obscure the entrance pupil of the lens from any part of the film. The outer parts of the filter would be so obscured, viewed from the margins of the film area. This defect will be more fully described later. Once the position of the filter has been fixed for exposing the film, this position becomes an inseparable characteristic of that particular film, and controls the true color reproduction. The illustration shows the color filter $(e,g,r)$ placed in front of the lens, as occurs in practice. Its virtual image appears at a distance $F$ from the film, the width $D$ representing the limiting diaphragm. Each of the cylindrical lenses embossed on the film produces a real, inverted, and reduced image of the tri-color filter in the focal plane of the embossed lenses, since the distance from the film to the filter, in comparison with the very short focal length of the embossed lenses, is practically infinite. The filter images replace the grains of the mosaic screen, each image corresponding to one of the previously mentioned screen units. The maximum width is equal to the width of one embossed lens, and its length extends over the entire height of each picture, in the direction of the axis of the cylindrical lens. However, the units do not carry their own real three-color screens, but look, so to speak, through telescopes to the one common color screen, placed in the limiting diaphragm of the lens. The film itself appears colorless under ordinary observation.

The development is the same as in the color screen process; *i. e.*

the original must be developed to a positive in order to obtain a direct reproduction in true colors. But while the color screen positive itself contains all colors, it is necessary to provide certain optical arrangements for projecting the lenticular films in true colors. This is not of particular advantage in motion picture work. The simplest arrangement would be to use for projection the same lens

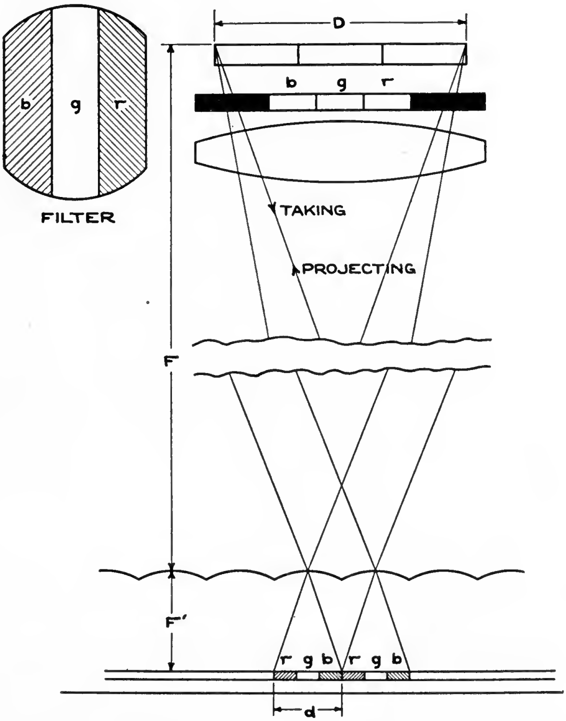


FIG. 1. Diagram of the optical system of the Agfacolor process. The cross-section of the film itself is shown at a much greater magnification than the objective and filters.

as used in the camera which would simply reverse the path of the exposing light. When lenses of other focal length and construction are used, care must be taken that the position and width of the color filter appear, from the point of view of the lenticular screen, identical to their relations during exposure. It is only then that, at the given focal length of the lenticular elements, the position and width of the

filter images behind the lenticular screen are identical to those of silver images formed by exposure and development of the film.

If the color value of the projected image is to be at its best, the screen must satisfy certain requirements:

(1) The real image of the filter as projected behind the lens elements must lie in the optical plane of the emulsion; the thickness of the film base and the focal length of the lens elements depend on each other. The focal length of the lenses, in turn, depends on the refractive index of the base and on the curvature of the lenses; hence the embossing of the screen must be done in a very particular way.

(2) The real filter images behind the screen should cover the aperture of the lens element in the same way as the filter covers the aperture of the camera lens. No light should be allowed to pass between the filter images, as the white light thus passing would weaken the color. The size of the real filter image behind the screen is determined by the following simple optical relation: If, according to Fig. 1, $D$ is the apparent width of the filter, as viewed from the film, and $F$ is the apparent distance of the filter, then $F/D$ will be the aperture at which the filter appears when viewed from the film. If we call $F'$ the focal length of the screen lenses, $d$ the width of the real filter image, and $n$ the refractive index of the film base, the following equation will result:

$$\frac{F'}{d} = \frac{n\,F}{D}$$

If the ratio $F/D$ is given by the focal length of the lens and the arrangement of the filter, then the maximum focal length of the lens elements is limited, as the width of the filter image can not be greater than the width of the cylindrical lens elements; or, by using a tricolor filter, the adjoining images on the outer filter strip would overlap, and red and blue colors would appear more or less purple.

(3) The narrower the individual screen lenses, the less the striped screen of the image will be visible on projection; on the other hand, the resolving power increases, and enables even the smallest images to be resolved into their details. Naturally, the grains of the emulsion should be small compared with the width of the stripes of the filter image. In the Agfacolor process, in which the width of the lenticular elements is 0.028 mm., the images of the individual color stripes have a maximum width of 0.009 mm., or twenty times that of the wavelength of green light. With respect to resolving power, the lenticular screen is superior to the mosaic color screen. Owing

to the geometrical coördination of the object, lens, screen, and image, details even smaller than the width of the lenses are reproduced in their correct position as regards color. With images smaller than one-third the width of the screen, mixed color details can not be resolved into their individual color elements.

(4) The quality of the pictures depends largely on the photographic qualities of the emulsion; particularly, on its color sensitivity. The latter, in turn, determines the choice of the filter colors with respect to their spectral transmission. The judgment and decision on this matter and the choice of the filter combination must be based merely on the principles of subjective psychology and on the average taste.

Theoretically, the lenticular films can be printed, but not by the ordinary contact method—numerous possibilities of doing this have been described and patented. It is important to preserve the original coördination between the density and the lens elements. The geometrical coördination between the silver grain, the lens elements, and the projection lens must be identical in both the copy and the original.

From the above it is seen that the characteristics of the lenticular film depend on the fact that the film itself bears the optical system that makes reproduction in colors possible. The quality of the projected picture depends a great deal on the degree of perfection of the screen. Consequently, processing, storing, and projecting require special attention. Grease spots, for instance, frequently encountered in motion picture theater practice, will change the optical properties of the screen or are likely to cause the entire screen picture to disappear.

As a support for an optical system, the entire area of the film must lie in proper relation to the lens and filter in both exposure and projection. Kinks or similar mechanical defects cause color distortions in projection. In addition to this, an exact adjustment of the camera or projection lens with regard to the film is very necessary. If, for instance, the projector aperture is not vertical to the optical axis of the lens, or if the film does not lie flat in the projector aperture, untrue colors will appear at the edges—so-called color dominants. Excessive drying of the film, which always causes some loss of solvents, also causes some displacement of the lens elements and is likely to disturb the projection. It is, therefore, advisable alway to store the film in air-tight cans.

With regard to transmission of light by the lenticular optical system, since the tri-color analysis is made with only one lens (for instance, a red surface would, when exposed and projected, use only one-third of the aperture; and, since the colors of the filters are not pure spectral colors, but contain some gray), there is greater loss of light in this process than in ordinary black-and-white photography. However, in motion picture photography, using lenses of short focal length and greater depth of focus, larger apertures can be used. The maximum usable width of the aperture is limited by the effective area of the lens in which there is no vignetting. If the filter were larger, parts of the lens mounting, or their virtual images, would obscure portions of the filter. This partial loss of one color would cause color dominants to appear at the edges of the picture when projected. For the same reason, it is impossible to use an iris diaphragm in order to reduce the amount of light. It is necessary to use neutral density filters (Eastman) or detachable slit diaphragms (Agfa). For exposure, lenses with relative apertures less than $f/2.0$ are hardly to be considered. The loss of light caused by the optical system can, to a certain degree, be compensated for by increasing the photographic sensitivity of the film. As the situation is at present, lenticular film can be used for outdoor exposures even under an overcast sky, and, under favorable lighting conditions, indoors.

Satisfactory projection can be obtained only with powerful projectors. Because of the loss of light, mentioned before, and for psychological reasons, it is necessary to have maximum brightness for color projection.

Before lenticular film can be introduced into motion picture theaters, some technical (not fundamental) difficulties must be overcome. First, it must be possible to make prints; second, the screen brightness must be sufficient. The requirements regarding illumination in the studio can be satisfied by increasing the sensitivity of the photographic emulsion. It is, however, difficult to solve the problem of obtaining satisfactory illumination on the large screens used in motion picture theaters.

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# THE PRODUCTION OF ANIMATED CARTOONS*

WILLIAM GARITY**

***Summary***—*This paper describes the general procedure employed in producing animated cartoons, particularly the technic employed by the Walt Disney Studios. The qualities required in the animators, and the problems that these animators must solve in realizing the dramatic situations and synchronizing them with the music and sound effects are discussed. An example of the procedure followed in producing the cartoon is given, including illustrations of the layout sheet, exposure sheet, and camera field charts.*

The method followed in producing a sound cartoon is basically simple. The degree of its success depends almost entirely upon the care and attention given to detail. The picture is built up frame by frame, and any tendency to overlook detail is reflected in the finished product. When one realizes that ten to fifteen thousand individual drawings are required for each complete production, it becomes clear why such great care must be exercised by all the production departments.

This company produces two series of cartoons, the *Mickey Mouse* and the *Silly Symphonies*. This year, the program calls for the production of a total of twenty-six cartoons, eighteen of which are to be *Mickey Mouse*, and eight *Silly Symphonies*. All the *Silly Symphonies* are to be released in "Technicolor."

In the *Mickey Mouse* cartoons, it has been the endeavor to build up definite personalities, not only of Mickey and Minnie, but of all the supporting characters as well. Every effort is made to maintain the same personality of each character in each picture, so as to establish that character in the mind of the public.

The *Silly Symphonies* are entirely free from any such limitation, and wide latitude is possible in selecting the subjects. It is the present intent to maintain this series in the realm of the unreal. The spirit of the seasons has been expressed in the subjects entitled

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** Walt Disney Studios, Hollywood, Calif.

*Springtime*, *Summer*, *Autumn*, and *Winter;* in others, the themes have been drawn from the fairy tales of old.

The principal difference between producing live-action subjects and animated cartoons lies in the fact that in live action, it is possible to rehearse the characters, see the immediate results, and select the best of several takes for the final product. In producing a cartoon, the director must visualize his action in terms of pen lines, plan his entire continuity, entrances and exits, dissolves and cuts; in other words, do all his editing, before a single picture is drawn. His only recourse, when his picture is finished, is to eliminate scenes. But it is not always possible to do this, because a recorded musical score is not as flexible as we sometimes wish it were.

In producing cartoons, it is necessary to analyze the story and break it down into several scenes, and to distribute these scenes among many individual animators. This requires that all the artists adopt a standard style of drawing, a difficult matter for an artist when he is entering the cartoon business. He must change his style to conform to the requirements of production. This is particularly difficult for an artist who has been developing his own individual style for any length of time.

Three types of men to be found in the cartoon business are: the artist, the animator, and the artist-animator. There are many men of artistic ability who find it impossible to create animated cartoons. There are also those who can animate, who can produce good action, but whose artistic ability is mediocre. The third group comprises the artist-animators, who combine the qualities of the other two groups.

Experienced men in this field are few and it is necessary, therefore, to maintain a group of apprentices of little or no production value, and to train them in the art of animation so as to be able to develop the organization. These apprentices are required to attend art classes at the studio. The period of apprenticeship lasts for about six months, never less, and often longer.

Very few men qualify in all branches of art. Some excel in characterization; others in mechanical action; others are particularly gifted in animating dialog; others have the ability to give subtle touches to action. They are all classified as to their ability, and as far as possible, are given those parts of the work for which their particular talents are best adapted. Considering the fact that an artist-animator can with diligence produce only five feet of action

every eight hours, it is necessary to conserve his time by assigning to him the kind of work he is able to do best.

In producing a cartoon, the first consideration is the story. If the story is good the results are usually gratifying. The finest music, the best sound recording and the most expert camera work, will never make a success of a cartoon with a poor story. As in live action, the director plays an important part in cartoon production. It is his function to present the story so as to make the most of its strong points and bolster the weak ones. He must visualize the action, build up the situations, and time the action so that nothing is lost. The selection of music and sound effects is his responsibility; and he must supervise the work of each animator in order that his ideas be carried out, in addition to supervising the recording of the music and effects. On him, as in live action, rests the responsibility of the picture as a whole. Next in importance are gags and situations.

Following in the order of importance, are the musical score and sound effects. The music must fit the mood of the picture in order to be effective: if properly chosen, it enhances the value of the story and the action; if improperly handled, it annoys and detracts. In the same way, certain sounds are effective in some situations, whereas the same sound in a different situation would be discordant and annoying. Sound effects should be adapted to the action; a sound effect should never be used unless the eye is conscious of the source of the sound.

The last items in consideration of a good subject are technical perfection, camera work, and sound quality. While we place these items last in importance, they are the ones that cause us the greatest trouble and require constant supervision.

The synchronization of sound to the cartoon is probably responsible, to some degree at least, for their success in the field. This one phase of producing cartoons is probably the least understood by the public, although it is perhaps the simplest part of the problem. Since the advent of talking pictures and the standardization of film speed, the problem became simply one of resolving all musical tempos in terms of the standard speed, and of making a consecutive series of drawings to fit this tempo. In order to do this, certain basic tempos, multiples of the frame speed of the film, have been established. For example, the fastest tempo employed is one beat every six frames, amounting to four beats per second. The total

range is from this to one beat every twenty frames, or one beat every $^5/_6$ths of a second.

The Story Department presents the most difficult of all the production problems. When one realizes that a picture must be released every fourteen days, the reason is quite obvious. The men in this department work continuously, developing material for pictures. The first step in the production of a cartoon takes the form of a rough draft of a story prepared by the Story Department. The following is an abstract of such a story outline:

United Artists Symphony No. 7, *Santa's Workshop;* Jackson, *director;* Churchill, *music.*

Story opens showing exterior of Santa's workshop at the North Pole—beautiful scene, snow falling, *etc.*, Santa's factory buildings.

Dissolve into an exterior of Santa's stables; little gnomes busily grooming the reindeer, washing their teeth, *etc.;* all busy and whistling, or some other musical effect.

This dissolves to the interior of the workshop, showing happy gnomes busily operating the quaint machinery; all gnomes whistle as they work. Show various closeups of individual elves making toys. Everything is run in the manner of the Ford factory. (Plenty of opportunities here for showing the ludicrous methods used by the gnomes in making the toys.)

Santa is the big boss who "okays" all the toys. He is happy and very good natured, and gets a big kick out of the various things the toys do. Santa could teach the dolls to speak and say "mama."

Amusing action of toys of various kinds, walking in their own individual ways. The toy band strikes up a snappy march and all join in a big procession leading to Santa's bag. When all the toys enter the bag, Santa picks it up, puts it into his sleigh, and drives off. Make a beautiful final scene, Santa disappearing in the sky in the distance, all the elves singing a Christmas song; just before the iris closes, show a silhouette effect of his reindeer and sleigh as they cross the Christmas moon, the voices of the elves coming in full volume for a final finish effect on the end title.

Everyone think this over and have some good "gags" ready to hand in at the next gag meeting. I expect a big turnout on this story. "Walt."

This story outline is mimeographed and handed to all the animators at a gag meeting. These gag meetings are held every two weeks for the purpose of discussing future pictures. The discussion is held within the limits set by the Story Department, outlined as above. Two weeks following the discussion of the story, the animators hand to the Story Department suggested gags and situations for the particular story. The Story Department then makes a complete study of the submitted gags and situations, and prepares a definite story outline in the form of a scenario. Then a conference

is held with the director and the musician, who are to produce the picture, at which the director is made acquainted with the story and assisted in preparing the continuity so as to preserve the original ideas and situations.

In this conference is included the "set designer," known as the "layout man." It is his function to prepare rough sketches of the complete scenes, depicting the atmosphere of the action, keeping in mind the movement of the characters. From these sketches, the background sketches are prepared and, finally, the finished backgrounds. In making the backgrounds, it is necessary to leave clear

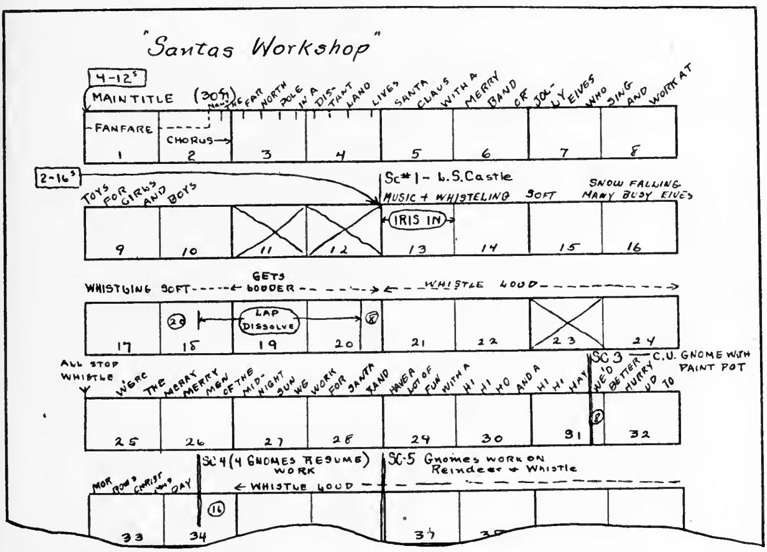


FIG. 1. Layout sheet used for planning the picture.

such portions as will later be occupied by the animated figures. The layout man must assist the director in maintaining good continuity of background, so that when camera angles are changed, the resulting background change will be smooth.

The director and the musician, at the end of this conference, have a very definite idea of the story, situations, and gags to be used; and the approximate footage of film that will be needed. The story is then laid out on a layout sheet, shown in Fig. 1. Each "box" (or small rectangle) represents a bar of music. How much of the picture is to be shown during each bar depends on the tempo

at which the music is to be played. Referring to Fig. 1, each box, starting at 1, covers 48 frames of action, the tempo being indicated as *4–12*. While working on the sheet, the musical director writes his preliminary master score. In some cases, when it is desired to use a certain piece of music, the director is required to adapt the action to the music. At other times, the action requires entire freedom from musical limitations, except with respect to tempo. In this case, the musician must compose music to suit the action. It is by means of the layout sheet that the entire problem is resolved, the action made to suit the music, and the music written to suit the action.

TITLE OF PRODUCTION: "SANTA'S WORK SHOP" -2-
PICTURE No.: U.S. # 7
STARTED
COMPLETED

| FOOTAGE | SCENE NO. | ARTIST | DATE STARTED | DATE COMPLETED | DESCRIPTION OF ACTION |
|---|---|---|---|---|---|
| 14-10 | 24 | BEN | | | M.C.U. PERMANENT WAVE. |
| 4-14 | 25 | KING | | M.C.U. | SANTA PICKS UP MAMMA DOLL |
| 15-6 | 26 | " | | S.A.25 | C.U. HER: TEACHES DOLL TO SAY "MAMMA" O.K.' |
| 37-2 | 27 | " | | S.A. 25 | M.C.U. SANTA INSPECTS MAMMY DOLL AND AIRPLANE. |
| 7-4 | 28 | BEN | | | M.C.U. PLANE KNOCKS TOYS OFF SHELF. |
| 11-14 | 29 | " | | | L.S. TOYS START TO MOVE. |
| 18-6 | 30 | " | | PAN | M.L.S. BAND AND SOLDIERS MARCH. |
| 35-10 | 31 | " | | PAN | M.C.U. VARIOUS TOYS IN PARADE. |
| 12- | 32 | GERRY | | | M.L.S. TOYS START INTO BAG (TRUCK) |

FIG. 2. A production schedule.

The director and the musician work hand in hand, measure by measure, frame by frame; each one trying to adjust his particular problem to meet the demands of the story.

When the layout sheet is completed, the director has his picture completely laid out to the frame, and the musician his master score to the note. Slight changes may later be made in order to accommodate the exigencies that may arise when the pictures are animated. It is everyone's desire to preserve the layout sheet as final, but necessity requires that it remain flexible.

The production schedule shown in Fig. 2 is next prepared. As will be noted, this schedule contains the scene numbers, the footage

of the scene, the name of the artist, and a description of the action to take place: scene *24*, the first scene on the sheet, is allocated a footage of 14 feet, 10 frames to be drawn by the artist, Ben, and to be a medium close-up showing a permanent wave. As soon as the schedule is completed, the director fills out an exposure sheet, shown in Fig. 3, describing in terms of frames of picture the continuity of the action, exactly on what frame the sound effects will occur, and what the nature of the sound will be. The tempo of the action is also shown on

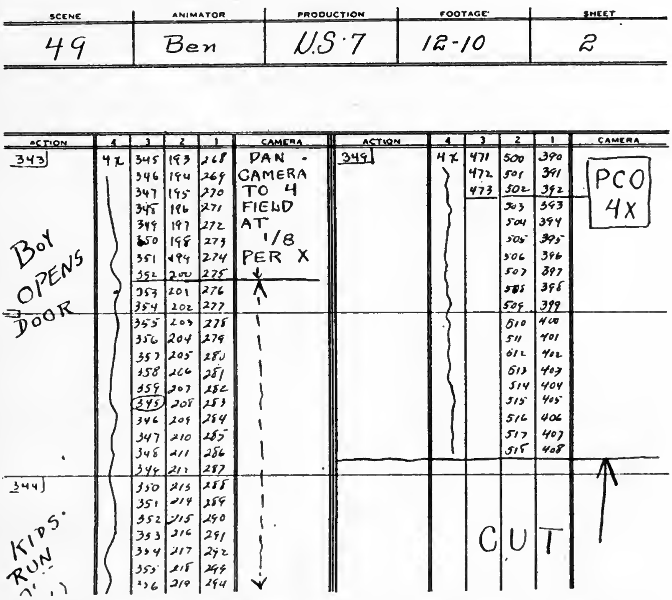


FIG. 3. Exposure sheet completely filled out, showing instructions for cameraman.

the exposure sheet. This exposure sheet is prepared with the assistance of the musician, who simultaneously marks on his master music score the exact position of sound effects.

The director, when preparing the exposure sheet, definitely instructs the animator as to the nature of the scene to be depicted, the exact footage that the scene should occupy, and the tempo of the music to be played during that particular sequence. The director also explains to the animator in great detail the relation of his sequence to the rest of the story, points out the particular gags or situations that are to be developed, and supplies the animator

with the necessary information concerning the preceding and succeeding scenes. The animator is also furnished with a background sketch which serves as his stage setting. It is the animator's function to visualize the scene in terms of pen-and-ink lines, and to produce a series of progressive drawings of the scene that will tell the story and the ideas incidental to it. The animator is quite limited, due to the fact that the musical tempo, as well as the footage of the scene, is fixed. He will sometimes find it necessary to shorten or to extend his bit of action to complete his sequences more effectively. In this case, he confers with the director; and if the latter approve such a change, the musician is consulted, who must rearrange the score to suit the change of footage. Such a procedure is avoided as much as possible, for obvious reasons.

As the animator makes his progressive drawings, he numbers them serially, recording them at the same time in the columns provided on the exposure sheet, in the order in which they are later to be photographed. The animator confines his drawings to a field approximately seven by nine inches. At the lower edge of the drawing paper outside the field are two perforated holes. These control the registration of the drawings. The animator's drawing board is provided with an insert of glass, under which is placed an electric light. On the edge of the glass insert nearest the animator, on the top surface of the drawing board, is placed a bar containing the registering pins, on which the paper is fastened. All drawings, including backgrounds, are made only when the paper is engaged by these pins. The paper used has a hard finish, and is very light in weight, so that tracing of images is facilitated.

Each animator has an "in-between" man or an assistant, and generally two apprentices. In order to conserve the animator's time, he makes drawings of only the extreme action, and makes a finished model as a guide for his assistants, who fill in the intervening drawings. For example: if the action require a walking character, taking 16 frames for a complete step, the animator makes drawings Nos. 1, 8, and 15, his assistant, or in-between man, making drawings Nos. 2 to 7, inclusive, and 9 to 14, inclusive. The assistant then hands the drawings to the apprentices, who fill in all the necessary detail.

When the animator has completed his particular scene, the drawings are turned over to the Inking and Painting Department, the function of which is to transfer or trace each drawing on celluloid sheets. These celluloid sheets are the approximate size of the paper,

and about $^5/_{1000}$ths of an inch in thickness. They are perforated with registering holes, identical to those in the drawing paper. The paper drawings are placed on the registering pins, the celluloid sheet is superimposed on the drawing, and a very careful tracing of the drawing is made with black India ink. After the tracing of the outline has dried, the celluloid is reversed, and the entire area occupied by the figures on the drawings is made opaque with paint.

The primary reason for using celluloids is an economic one. If the transparency were not used, it would be necessary to draw a complete background for each frame of the picture, which, of course, would be an economic impossibility. To avoid doing this, a single background is drawn, the characters working against this background being traced on the celluloid sheets. As the entire area occupied by the character is rendered opaque, the background is completely matted out by the character when the celluloid sheets, inked and painted, are superimposed on the background. It is possible to have a large number of characters, each doing something different, by tracing each character on a separate sheet of celluloid, and simultaneously superimposing these celluloid sheets upon the background. The use of many such celluloid sheets aggravates the photographic problems, due to the light losses and color changes introduced by the celluloid. Four sheets seem to be the greatest number that may be used without seriously affecting the photography.

For rendering the celluloid sheets opaque, white, black, and five shades of gray paint are used. When a number of characters are superimposed simultaneously on the background, 1, 2, 3, or 4 sheets of celluloid are used. In order to produce the same color value in the negative, five different shades of gray paint must be employed. The darkest shade is used on the top sheet and the lightest on the background. This is necessary because of transmission losses inherent to the celluloid. The thickness of the sheet is also a factor to be considered; and for that reason all sheets are carefully graded as to thickness and color, in order to minimize the painting problems and reduce density changes in the half-tones of the film.

After the picture is photographed, all traces of the ink lines and of the paint are removed by washing, thus reclaiming the sheets for later use. In practice, the celluloid sheets are never used more than three times, due to the fact that the surfaces become badly scratched and marred when used more often. Also, after the third time, the celluloid becomes discolored, an effect impossible to control by

means of the paint. Also, as the celluloid ages, shrinkage becomes a serious factor, preventing the sheets from fitting properly over the registering pins.

After the celluloid sheets are completed by the Painting Department, they are turned over to the Camera Department for photographing. A standard Bell & Howell camera is employed, equipped with a stop-motion mechanism driven by a synchronous motor. The camera can be moved vertically to change the size of the field, as well as from right to left (east and west), fore and aft (north and

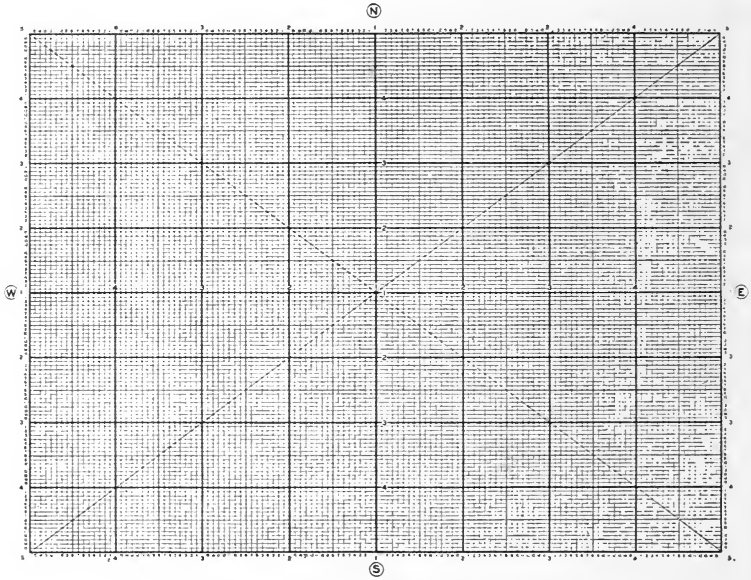


FIG. 4. Camera field chart; used for orienting the optical center of the camera.

south), and rotated through an arc of 360 degrees. The optical center of the camera is oriented by means of a "camera field chart," shown in Fig. 4. A copy of this chart is in the hands of each animator. The calibration of this chart is identical to that of the scales on the camera. Fig. 5 shows a photograph of the cartoon camera and camera stand.

The celluloid sheets representing the action of a single frame of the picture are assembled and placed over the background of the scene. The "cels" are held in position by registering pins. An optical glass plate flattens the "cels" against the background, thus

removing any wrinkles or curl. The glass plate is operated by a compressed air mechanism.

If less than four "cels" are required for the action, blank "cels" are added so as to preserve the photographic values of the background. Four "cels" are always used between the camera and the background. The camera operator follows the instructions outlined on the exposure sheet. A completed exposure sheet is shown in Fig. 3.

FIG. 5. Cartoon camera in camera stand.

Approximately 100 hours are required to photograph a cartoon subject, which averages about 600 feet of film. If the subject should contain more than the usual number of so-called "trick" shots, which may require complete camera readjustment for each frame of film, the shooting time will easily run from 125 to 150 hours.

During the time consumed in animating, inking, and photo-

graphing the picture, the musical score is completed and arranged, and the sound record is made. It is not necessary for the purpose of scoring to see the picture. As the musical score is prepared in accordance with the same tempos as those used in drawing the pictures, the musical director knows exactly at what frame in the picture every musical note or sound effect will occur.

Not only are parts written for all the instruments in the orchestra,

FIG. 6. Recording a Mickey Mouse cartoon; trap drummer's table in center. Note the head-phones used by each member of the orchestra.

but each trap drummer, or effect man, is supplied with a score that is as complete in detail as is the part for the first violin. The position of the effects is written on the score as musical notes, postscripts being added to describe the kind of sound or effect required. The trap drummer must be able to read music and to assign proper values to the sounds as indicated by the musical notations.

Each member of the orchestra, as well as the conductor, is provided with a head-phone (see Fig. 6) similar to that used by telephone operators, in which is heard the tempo of the music to be played. This beat is developed by means of an audio-frequency oscillator

controlled by a synchronously driven contacting device, which makes and breaks contacts in terms of frames of synchronously running film. Experience has shown, after trying perhaps every known method of achieving perfect synchronism, that the aural process thus employed is as nearly fool-proof as any system could be. The Disney Studios were probably the first to synchronize cartoons by projecting a wavy line to be used as a tempo guide, or the use of the bouncing ball. These two methods were abandoned, after a brief trial, in favor of the present method. For scoring the cartoons, there are employed an orchestra ranging from twelve to twenty musicians and four, and sometimes five, effect men for producing sound effects, in addition to the vocal artists. To synchronize the orchestra is relatively easy; the greater problem is to synchronize effects, because of their unmusical character and irregular occurrence. The effect man has quite a problem, as he sometimes has on his table dozens of sound producing devices, which he must pick up and operate at very definite places in the score. With the aural method of controlling synchronism, he is constantly aware of the tempo, and his attention can be concentrated on his musical score and effects. It is not necessary for him even to follow the lead of the conductor, except at the start. The actual recording technic is approximately the same as used to record any orchestra.

To facilitate cutting the sound track, acoustical beats are recorded at the beginning and at the end of the take. These beats are controlled by the musical director. A predetermined number of beats are produced in synchronism with the controlling tempo, followed by a predetermined time interval in which no sound occurs, preceding the first bar of the music. This enables the cutter to determine, with absolute accuracy, the exact start of the sound take. It is quite possible, and has been the practice of this studio, to assemble the sound track from these visible indications on the film, assemble the picture negative from the exposure sheets, attach academy trailers, and make a composite print. Errors in the synchronism are due to errors in supervision.

The dialog is handled in a somewhat different manner. In the case of dialog that does not follow the tempo of the music, prescoring is necessary: the dialog is recorded before drawings of the subject are made. The recorded sound track is sent to the Cutting Department, where a careful analysis of the position on the film and of the various speech components is made; such components being

translated into terms of frames on an exposure sheet. The exposure sheet then indicates to the animator the exact position of each and every syllable in the dialog and the drawings are made to fit the particular conditions. In the case of musical or rhythmical dialog, it is possible for the animator to make suitable drawings for the words to be used, and in this case the dialog is recorded at the time the orchestral recording is made. This form of dialog is one to be avoided, as in the finished product the composite result sometimes lacks realism; whereas in the first method of prescoring, it is quite possible to make the audience feel that the cartoon character is actually talking.

# A METHOD OF MEASURING AXIAL CHROMATIC ABERRATION IN AN OBJECTIVE LENS*

W. HERRIOTT**

***Summary.***—*A method of measuring axial chromatic aberration is described in which an image of a line grating test object illuminated by a monochromator is formed by the lens under test. The image thus formed is projected onto a steeply inclined photographic plate by means of a highly corrected microscope objective. Individual exposures are made at selected wavelengths and a curve showing the change of image position as a function of wavelength for the lens under test is readily derived from measurement of the developed plate. Data are given showing the order of agreement attained between computed values of axial chromatic aberration and values obtained by this method.*

No commercially available photographic lens offers perfect definition over an extended field because of the influence of inherent aberrations. The aberrations are usually so distributed as to result in the best possible average definition over the required picture area. In general, such a lens is of high relative aperture and is intended for use with an object distance that is many times its focal length. Commercial considerations have, in certain cases, led to the development of special types of lens systems where the lens designer has been able to meet requirements imposed by special needs. The process lens is illustrative of this type. In this case, corrections are effected at a low relative aperture for a magnification of approximately unity, and particular care is given to the correction of lateral chromatism as this aberration would obviously prohibit precise registry of negatives made through trichromatic filters.

Many physical instruments are now in use in which photographic methods are employed to record a wide variety of transient phenomena. The modern high-speed oscillograph is representative of this type of instrument; and such instruments, in general, employ a lens system as a means of imaging an aperture on the plane oc-

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cupied by the light-sensitive material. Such imagery may be effected under a wide variety of conditions for which certain optical factors may not receive proper design consideration. Such factors involve the brightness and energy distribution of the light source, the magnification adopted, and particularly the extent of the angular field required. Factors relating to photographic materials, such as resolving power, spectral sensitivity, contrast, and speed, are of equal importance. We frequently observe instances where commercially available lenses have been applied to these uses under conditions widely different from those for which such lenses were originally designed.

As suggested above, particular considerations may justify the design of special lens systems in which improved optical efficiency may be attained by giving close attention to the influence of the various factors that determine the performance of the instrument. In some cases, sharp definition may be required only over a limited field and under conditions where a lens of low relative aperture can be employed. In case a photographic material of low speed is used, it may be necessary to increase the relative aperture to a point where the definition will be affected.

At the Bell Telephone Laboratories consideration has been given to the choice of a lens system that is required to work with a low-speed emulsion under illumination conditions that necessitate the use of the high relative aperture of $f/1.5$. It is also necessary that this lens shall give the best possible definition over a limited angular field of approximately 3.5 degrees. The object consists of a small illuminated rectangular aperture, which is imaged at the film plane at a magnification of approximately 0.5. The particular lens that was used for this purpose served well until it became desirable to increase the sharpness of the image. Lens bench examination of the image structure indicated the presence of axial chromatic aberration.

A photographic method of measuring axial chromatic aberration has been applied to a study of this and similar lenses. The method involves the projection of an image formed by the lens under test onto a steeply inclined photographic plate.

Fig. 1 shows schematically the apparatus used. The slit of a constant deviation spectrometer is illuminated by a small coil filament tungsten lamp and condenser. These units are adjusted to form an out-of-focus image of the closely spaced coil filament at the slit. The eyepiece of the spectrometer has been removed, and a test

object consisting of five transparent lines 0.001 inch wide and 0.250 inch long, separated by opaque lines of the same dimensions, is placed at the approximate focus of the telescope objective. Immediately behind this test object is located a small piece of finely ground glass, which serves to permit filling of the aperture of the lens under test, which is shown to the right of the test object. The lens under test forms an image of the test object at a magnification of 0.5. The total width of the test object is limited to 0.010 inch, in order that a reasonably pure monochromatic radiation will be transmitted to the lens. A 16-millimeter Bausch & Lomb apochro-

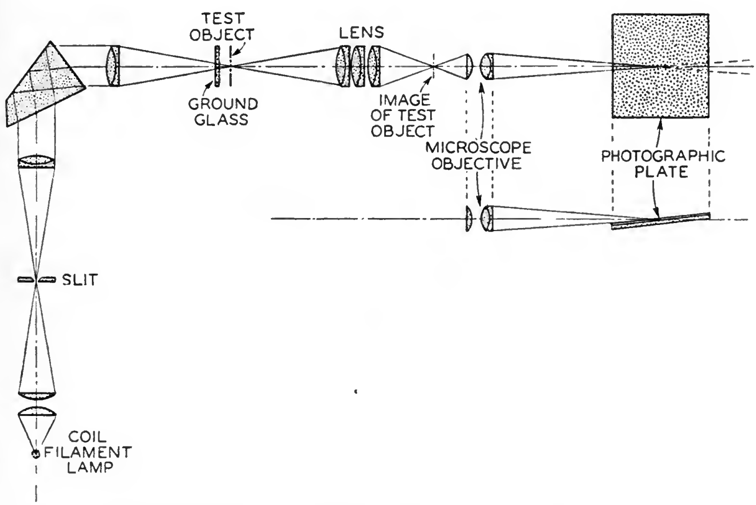


FIG. 1. Schematic diagram of apparatus for measuring axial chromatic aberration.

matic microscope objective serves to relay the image of the test object formed by the lens under test to a steeply inclined photographic plate at a magnification of 10.0. The image formed by the microscope lens lies, of course, in a plane perpendicular to the optical axis, and the inclined photographic plate records a trace of the focal region surrounding a focal point. The position of the constant deviation prism in the spectrometer can be altered, and a reading of the wavelength scale indicates the wavelength of the radiation incident upon the test object. Assume that a wavelength of 4000 Å is illuminating the test object, the lens under test will form an image

of the test object that will lie at some distance in advance of the first principal focal point of the microscope objective. The image formed by the microscope objective will lie at a definite distance to the rear of its second principal focal point. If an axial movement of the image of the test object formed by the lens under test occurs, it is obvious that a shift of the image formed by the microscope objective will also occur.

A series of exposures is made on a single plate. These exposures differ only in respect to the wavelength of the light incident upon the test object. If the color curve is not flat, the images of the test

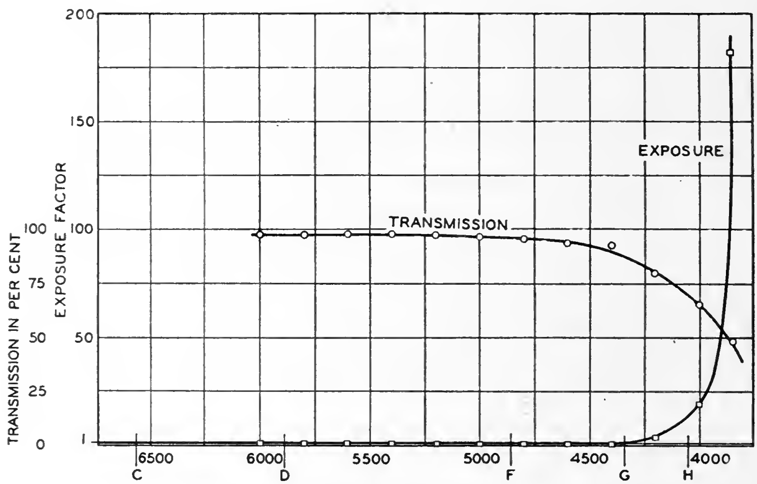


FIG. 2. The transmission characteristics of the dense flint prism used in spectrometer; also a correcting factor applied to exposures to compensate for the loss.

object formed by the lens under test will occupy different image planes. This shift of image plane with wavelength will be indicated on the inclined photographic plate as a change in position of the point of sharpest definition. This change in position will, of course, be a function of the wavelength of light used, and is directly dependent upon the nature of the axial chromatism of the lens under test. In this manner we can trace a curve connecting the series of points on the inclined photograph, which will represent on a greatly enlarged scale the values of axial chromatic aberration of the lens under test.

The dense flint prism used in the spectrometer exercises a high absorption in the ultra-violet region. Fig. 2 shows the transmission characteristic of this prism, and also shows a correction factor that is applied to exposures in order to compensate for this loss.

Fig. 3 has been made in the above described manner, and shows a

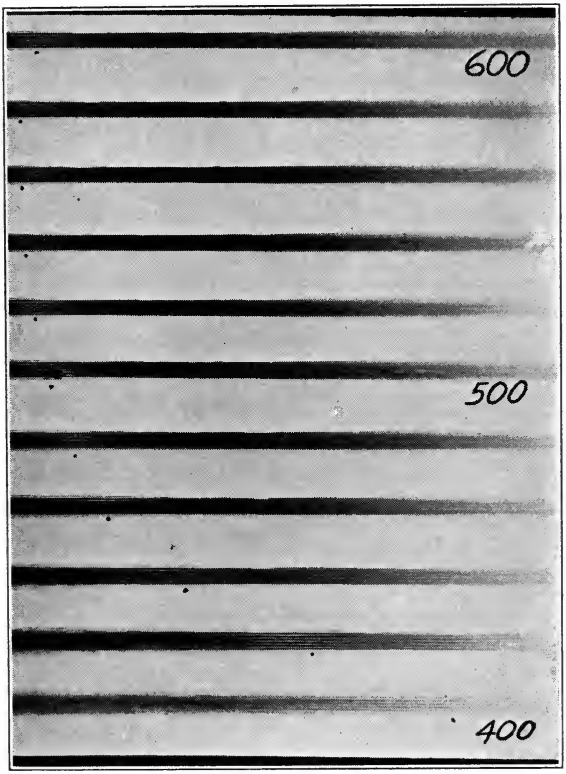


FIG. 3. Plate combining series of exposures showing shift of image plane with wavelength; the dots show roughly the points of sharpest definition.

change in the point of sharpest definition as a function of wavelength. The black dots serve only roughly to locate the various points of sharpest definition.

Fig. 4 shows a comparison between computed values of axial chromatic aberration and values obtained by three methods of measurement. A curve is shown that represents a visual examination

of the lens in which a ten-power eyepiece was used with the 16-mm. apochromat micro-objective in the normal way. A direct-reading micrometer gauge was attached to the microscope, focal settings

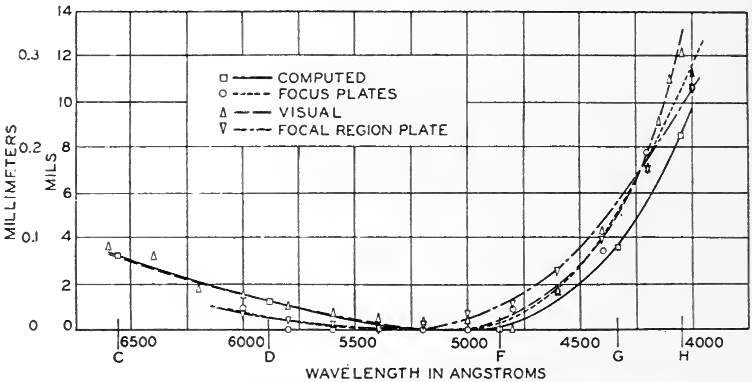


FIG. 4. Comparison between computed values of axial chromatic aberration and values obtained by three methods of measurement.

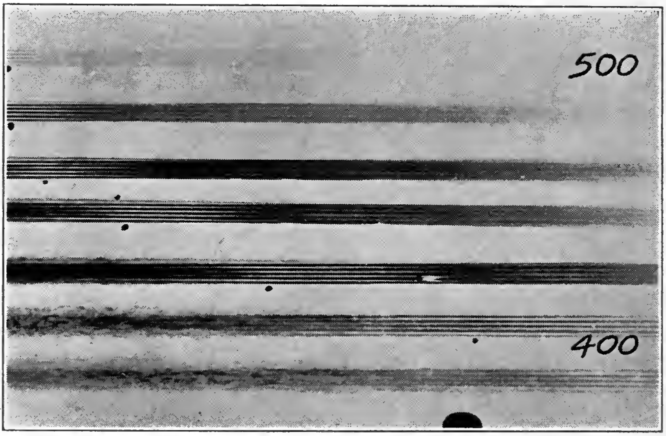


FIG. 5. A focal region plate made on a process type of emulsion; exposure constant for all wavelengths.

were made on the image of the test target visually, and the differences were noted. A curve is also shown, designated "focus plates," which resulted from an examination of an extended series of photographs of the image of the test object obtained with the 16-mm. micro-

scope objective when the photographic plates were placed normal to the optical axis of the objective. The microscope and plate were moved longitudinally through an extended range, and many exposures made at definite settings for each selected wavelength. This process was repeated at all desired wavelengths; a visual examination of the plates indicated the location of the plane of sharpest definition, and a curve was readily plotted that shows these results in graphical form. The fourth curve was derived from the focal region plate shown in Fig. 3. An average curve would result in a departure of less than 0.001 inch between the computed

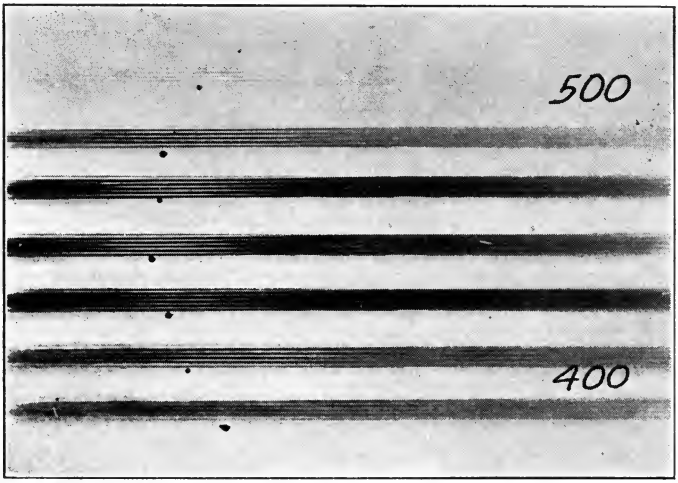


FIG. 6. A more favorable condition attained by using a newly designed lens.

and all the observed values. The particular lens used for these tests has an equivalent focal length of 1.500 inch.

The photographic emulsion with which this lens is used is sensitive only to the blue and violet, and Fig. 5 shows a focal region plate made on a process type of emulsion for which a constant exposure has been given at all wavelengths. It is obvious that the greatest photographic effect occurs at 4200, 4400, and 4600 Å, with a lesser effect at the other wavelengths shown. This figure shows clearly the unfavorable state of axial chromatic correction that exists in this lens over the portion of the spectrum to which this material is sensitive.

Consideration of these results by the lens designer has led to the design of a new lens for which a much more favorable condition is attained, as shown by Fig. 6. Fig. 7 shows this correction plotted on the same scale used on Fig. 4. The departure from a flat characteristic is of the order of 0.001 inch at 4000 and 5000 Å. At intermediate values where the radiation is most effective in building up density, we note that the curve is essentially flat. Fig. 8 represents focal region exposures for both the above-mentioned lenses, made in a

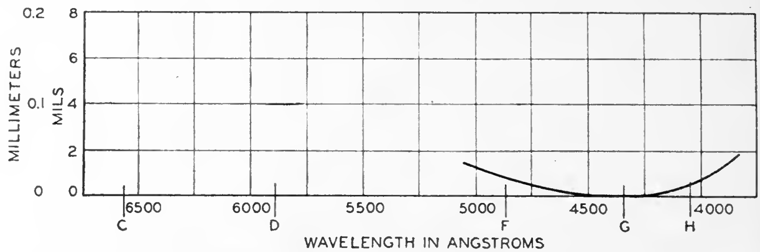


Fig. 7. The correction in Fig. 6 plotted on the same scale as in Fig. 4.

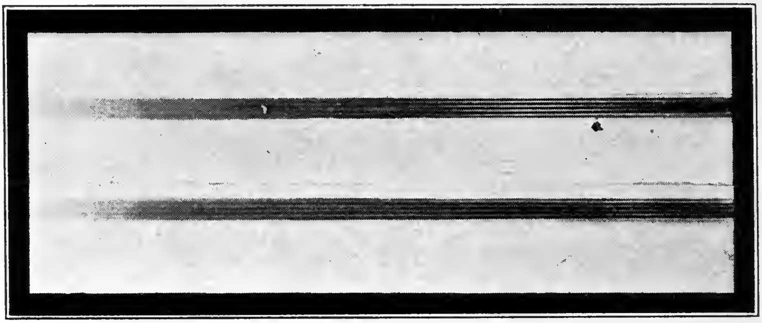

Fig. 8. Focal region exposures for the two lenses.

similar manner, excepting that the spectrometer was removed and the tungsten light source focused directly on the test object. A difference in the quality of definition offered by these two lenses is readily shown. Contrast is decidedly improved with the new lens, and other tests have indicated a very definite improvement in sharpness of the image. Fig. 9 shows values of axial chromatic aberration for the 16-mm. apochromat microscope objective as determined visually at Bell Telephone Laboratories, and also shows the corre-

sponding values derived by computation. The author wishes to acknowledge the courtesy of the Bausch & Lomb Optical Company in making these data available. These values were obtained in order to determine the possible influence of the characteristics of the microscope objective on the results obtained with the focal region plate method.

It is obvious that the apochromatic type of objective offers a very flat color characteristic over an extended wavelength range. Such lenses can be manufactured in the smaller sizes with a high relative aperture, and can be corrected for the desired magnification. The increasing use of this type of objective might be expected where

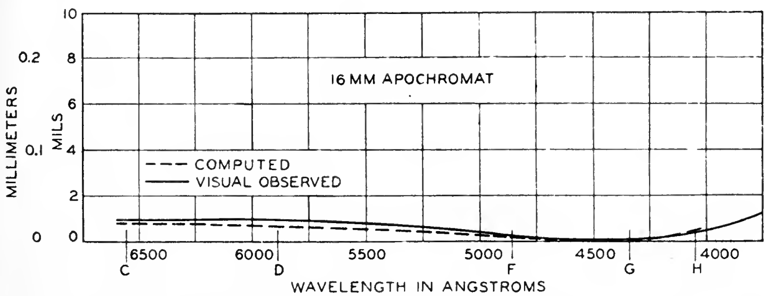


FIG. 9. Axial chromatic aberration for the 16-mm. apochromat microscope objective; also corresponding values derived by computation.

critical definition is required over a narrow field. The limit in the size, focal length, and aperture that can be obtained with the apochromat construction appears to be established by the availability of suitable material for its construction.

Consideration is being given to the possible application of the above-described method of test to the measurement of spherical aberration in lenses. The use of a single rectangular aperture at the test object, together with a series of apertures immediately in front of the lens under test, may serve to make possible the accurate determination of crossing distances for the various zones of the lens.

# A NEW WAY OF SPLITTING SECONDS*

C. H. FETTER**

***Summary.***—*In timing races by the usual method employing a manually operated stop-watch, errors are liable to arise independently of the accuracy of the timepiece. In order to eliminate this cause of error, a system of timing races has been devised employing a motion picture camera, with which are photographed a very accurately adjusted chronometer at both the beginning and the end of the race, and the contestants themselves at the finish line. This system has been applied successfully at recent important athletic meets held in the U. S.; particularly at the Xth Olympiad held at Los Angeles in 1932.*

From the earliest recorded history of man we have seen evidence of human interest in all sorts of athletic sports. Track and field events were popular in the days of ancient Greece and our present Olympic Games originated there centuries ago. Not only has man always been interested in the purely competitive angle of racing events, but in recent years he has become more and more interested in the performance of the individual with respect to time, in addition to his performance against a suitable competitor. On this basis national and world records have been established in order to classify the performance of the individual in terms of an invariable quantity such as time, where a contestant may compare his own performance either with that of some one who preceded his athletic activities, possibly by years, or with other contestants in different localities.

In dealing with this so-called invariable quantity, time, the ordinary method employed of timing a race has been by means of a stop-watch. Until several years ago stop-watches giving time to a precision of one-fifth second were used, but more recently tenth-second stop-watches have been universally employed. In track work, for example, the competitors are started by the firing of a gun. The timers are usually located near the finish line of the race in order to time the finish properly. The timer operates a stop-watch at the flash of the gun when the race is started, and operates it again as the

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** Electrical Research Products, Inc., New York, N. Y.

runner crosses the finish line. This procedure inherently contains the possibility of three errors: (1) it is practically impossible for a human being to operate a stop-watch coincident with the firing of the gun because of the human reaction-time involved; (2) it is extremely difficult for a timer to operate his stop-watch at the finish of the race coincident with the man's crossing the line, and while this error is probably less than the starting error because the timer has an opportunity to anticipate the finish, it is still very much in evidence; (3) the watch itself by virtue of being built for a precision of a tenth of a second would register the nearest tenth when the timer has operated it. In addition, there is likely to be an accumulative error in a stop-watch depending upon its adjusted rate as a timepiece.

In addition to the question of time performance, judging a race is by no means a simple problem. In a close finish it may be very difficult to decide not only who is first, but also the order of finish of, for example, the first five. A runner may be blanketed by a competitor so that the judge is confused as to which runner he is called upon to judge. As a matter of fact, in an important meet not long ago a man who ran second was not placed at all because of the human error in observation.

This state of affairs in regard to track events has been known to exist for some years. Four or five years ago Mr. Gustavus T. Kirby, Chairman of the Advisory Committee of the Intercollegiate Association of Amateur Athletes of America (I. C. A. A. A. A.), who has been interested in amateur sport activities for many years, conceived the idea of photographing the finish of a race in order to determine the proper position of the contestants. He included in this the idea of somehow photographing the time of the contestants as well, and in 1931 he used a motion picture camera that photographed both the finish of the race and the face of an ordinary stop-watch. The scheme that he used was that of starting the stop-watch before the race was started, and recording on the motion picture film a flash of light operated by a contact in the starter's gun. By subtracting the readings on the photograph of the stop-watch at the beginning from those of the finish of a race the time could be determined to the nearest tenth of a second.

In the summer of 1931, several individuals at Electrical Research Products, Inc., were discussing the possibilities of applying to the problem in some way Bell System technical knowledge of precision timing work. This was done in complete ignorance of any progress

that had been made along this line and, strangely enough, the same conclusion was reached that was found by Mr. Kirby and his associates; namely, that the only satisfactory method by which a race could be timed and judged was to use a high-speed motion picture camera arranged to photograph both the performance and the time. Obviously, this process would provide a permanent record of each event, which would be of value.

Through a fortunate occurrence in endeavoring to investigate the situation those engaged in the work met Mr. Kirby and discussed the problem with him. They were extremely interested to learn of his activity along this line, and felt that the company could make a very important contribution to the improvement of timing apparatus, in that it could build a frequency standard that would permit timing if necessary to one one-hundredth or even to one one-thousandth of a second. The need of such precision in timing a foot-race becomes evident when it is realized that in the faster races, including races as long as a half mile or a mile, a man may run a yard at the finish in a tenth of a second. After discussing this matter with Mr. Kirby, work was begun to develop suitable apparatus for experimental use at the I. C. A. A. A. A. and the Olympic Games in 1932, for which permission had already been granted.

Before design of the apparatus was begun, at least on a model basis, several preliminary requirements as to its operation were established: (1) it was decided that for this use a precision of 0.01 second would be satisfactory, as such timing is accurate to within three or four inches in the position of the runner; (2) use of the photographic method appeared absolutely essential; (3) it was considered desirable to devise a means of photographing the reading of the clock at the finish of the race to show the actual time of the runner. This meant that the clock must be reset to zero before the start of the race and be started practically instantaneously with the firing of the gun. The Bell Telephone Laboratories were asked to design a tuning-fork generator and a motor-driven clock mechanism that would meet these requirements.

In the development of this system it was decided to make two clocks, one associated with the camera, with which the time and the finish of the runner could be photographed adjacently on the same film; and another, that could be started in the same manner as the first so arranged as to be hand-stopped, so that one of the timers could use this precision clock as a sort of "glorified" stop-watch, by

means of which the time, except for human error at the finish, could be read to the hundredth of a second immediately following the race.

The system that was developed consists primarily of a 200-cycle tuning-fork generator which drives a synchronous motor at a speed of ten revolutions per second. The motor shaft is connected to a clock mechanism by means of a magnetic clutch so arranged that the clock

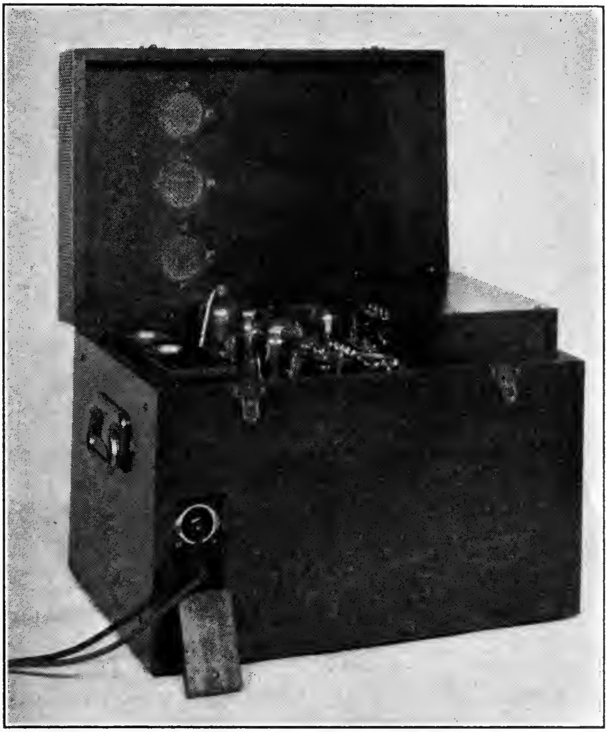


FIG. 1. The 200-cycle generator.

dials, which are normally reset to zero and are stationary, are set in motion when the starter's pistol is fired.

In designing the clock-work itself, some consideration was given to the type of record to be obtained. First of all, it was decided to use a standard 16-mm. camera, which takes 128 pictures per second. Inasmuch as most of the picture area in the 16-mm. film must be devoted to the action of the contestants, it was decided to use three

rotating dials and a fixed hair-line in order to obtain the time on the film in the largest possible characters. By the use of rotating dials it was necessary to photograph only a small segment of the entire dial arrangement. Three concentric dials were used. The inner dial rotates at one revolution per second and has one hundred divisions on it. The middle dial rotates at one revolution per minute with sixty divisions, and the outer dial rotates at one revolution

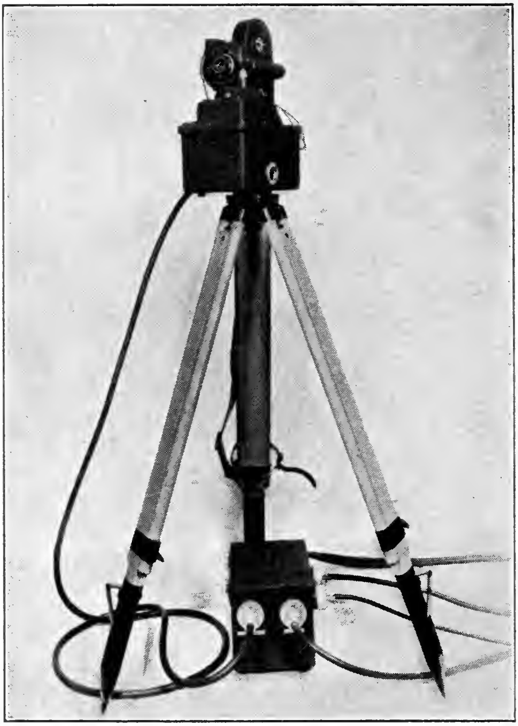


FIG. 2. Assembly of the camera, clock, and control box.

per hour with sixty divisions. Thus minutes, seconds, and one-hundredth seconds can be conveniently read.

Fig. 1 shows a photograph of the 200-cycle generator used in this model and Fig. 2 shows an assembly view of the camera, the clock, and a control box designed to provide the necessary power. The whole system is operated from alternating current of 110 volts.

FIG. 3. The first race timed with this system; New York, May 14, 1932.

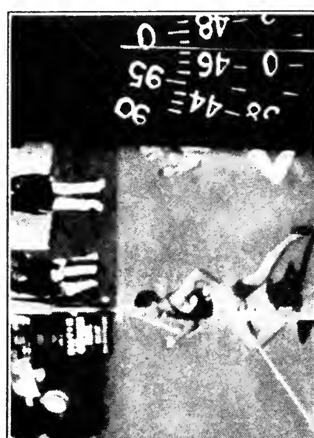


FIG. 4. Showing the end of a race at Berkeley, Calif., July 1, 1932.

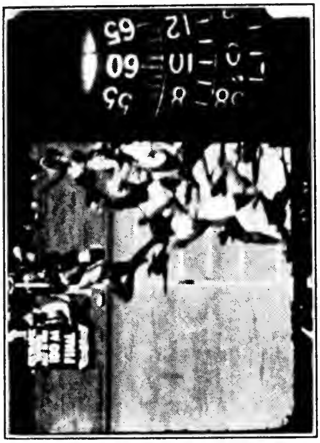


FIG. 5. The finish of a race at the American Olympic try-out, Palo Alto, July 15, 1932.

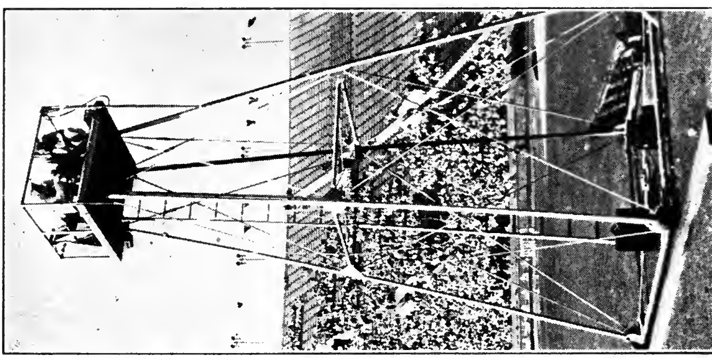


FIG. 6. The tower on which the camera clock was located at the Xth Olympiad.

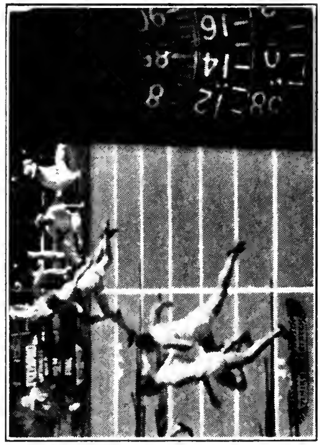


FIG. 9. Showing how the time of each contestant is determined, as well as that of the winner.

The optical system provided to photograph the clock dials can be seen at the left rear end of the main camera lens assembly.

This system was first tried out at the Columbia-Syracuse track meet at Baker Field, New York, on May 14, 1932. Fig. 3 shows the first race to have been timed with this system. It was the 100-yard dash, in which the time as shown to the nearest hundredth of a second was 10.26 seconds. At the Princeton-Cornell meet at Princeton on May 21, 1932, the system was successfully demonstrated, and on June 19, 1932, the apparatus was sent on the Intercollegiate special train which ran from New York to Berkeley, California, for demonstration at the I. C. A. A. A. A. meet there on July 1 and 2.

An example of the results obtained at Berkeley is illustrated in Fig. 4, which shows Carr of Pennsylvania winning the 440-yard dash in 46.99 seconds. Even though the camera operates at such high speed, all the final events on Saturday, July 2, were recorded on less than 60 feet of film, because the camera is operated only as the runners cross the finish line.

At Palo Alto on July 15 and 16, the American Olympic tryouts were held, and photographs were obtained of the finish of every "heat" and "final" at those tryouts. As an example of how difficult it is to judge a race, Fig. 5 shows the finish of the 100-meter final at these tryouts. Metcalf finished first in a time of 10.62 seconds, but there were at least four runners who were not more than a yard or so behind him. Such a grouping of runners shows how difficult it is to judge a close race by the eye alone. Note that the camera position is above the finish line as well as in line with it so that it becomes less difficult to judge the finish properly. At Palo Alto on July 16, the film was shown to the American Olympic Committee, and great interest in the timing system used was expressed. As a matter of fact, the committee confirmed one of its own decisions through the showing of the pictures, and reversed the fourth and fifth positions in one event because of the camera evidence.

From July 31 to August 7, inclusive, this apparatus was in use at the Xth Olympiad held at the Olympic Stadium in Los Angeles, California. A few days prior to the opening of the games some of the pictures taken at Palo Alto were shown to the Olympic Committee, and based upon that evidence the following status was given the timing system: (1) it would be used officially for judging; (2) the hand-stopped clock associated with the system would be used as

one of the timers, of which there were five; (3) it would be used officially for timing the decathlon.

The camera clock was located 60 feet back from the finish line and on top of a 25-foot steel tower, as shown in Fig. 6. Throughout the Olympics every trial, semi-final, and final was timed. Fig. 7 shows Tolan breaking the world's record in the 200-meter run with a camera-recorded time of 21.12 seconds. His official time for this race was 21.2 seconds. Fig. 8 is interesting because it shows one of the official photographs taken from the top of the judges' stand for this same race. In the lower left-hand corner can be seen the hand-stopped clock; and the timer, who is operating it, is kneeling in the immediate foreground. Fig. 9 shows Lord Burleigh of England in fifth place of the 110-meter hurdles. This illustrates how the time of each contestant can be determined, as well as that of the winner. This picture is also particularly interesting because it was in this race that Finlay of Great Britain was awarded third place, reversing the decision of the judges, who had awarded it to Keller of the United States before the pictures were seen. The foot of the winner is just visible at the left side of the picture and Finlay is running in lane 3. Keller of the United States is running in lane 7, the farthest one from the camera. Two other decisions of a minor nature were reversed by the judges after seeing the pictures.

As an example of how the official times compared with the recorded photographed time, figures are given below for some of the Olympic finals:

| *Race* | *Official Time* | *Camera Time* | *Difference—Official Time Used as Reference* |
|---|---|---|---|
| 100-Meter Run | 10.3 | 10.38 | +.08 |
| 110-Meter Hurdle | 14.6 | 14.57 | −.03 |
| 200-Meter Run | 21.2 | 21.12 | −.08 |
| 400-Meter Run | 46.2 | 46.28 | +.08 |
| 400-Meter Hurdle | 51.8 | 51.67 | −.13 |
| 800-Meter Run | 1:49.8 | 1:49.70 | −.10 |

At a meeting of the International Amateur Athletic Federation after the games were over, this body in an official report praised the use of the timing system and recommended that hundredth-second timing be adopted as a world standard. It also officially invited us to time the Olympic Games to be held in Berlin in 1936.

While at the Olympic Games in California, Mrs. Amelia Earhart

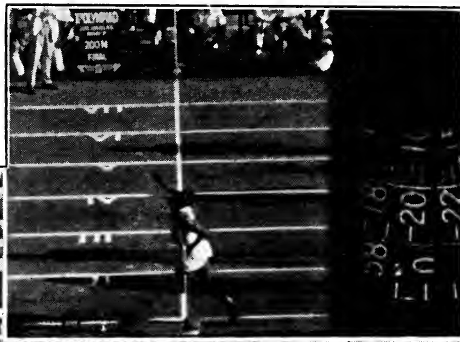
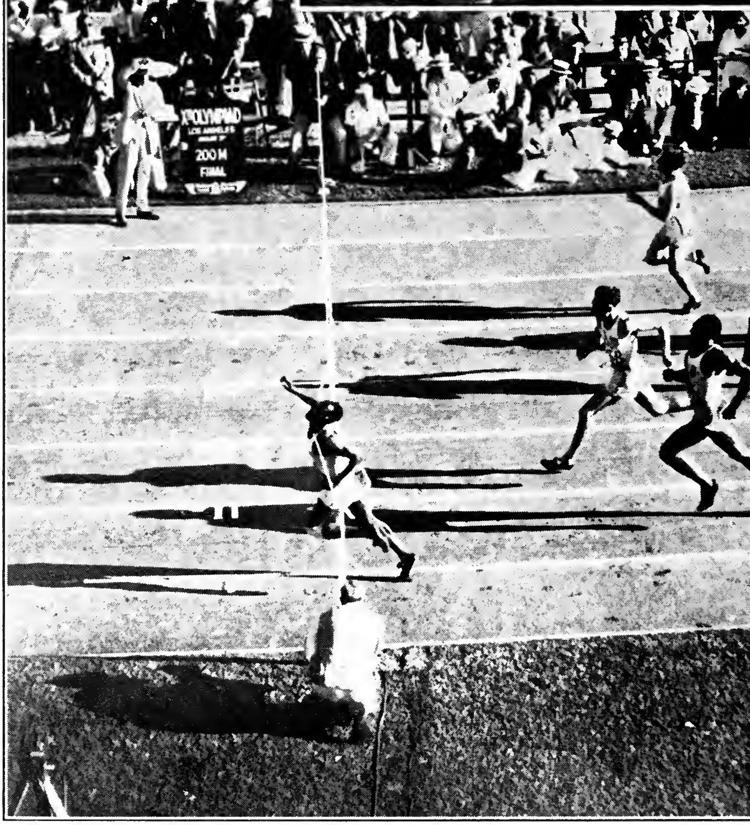


FIG. 7. The finish of the 200-meter race at the Xth Olympiad.




*Xth Olympiad Committee, Official Photograph*

FIG. 8. An official photograph taken from the judges' stand

Putnam, having seen and heard of this method of timing, stated that it should certainly be used for airplane races. As a result of this statement, the National Aeronautic Association was approached; and through the courtesy of Dr. Lewis and other members of the Contest Committee, the apparatus was used in collaboration with the

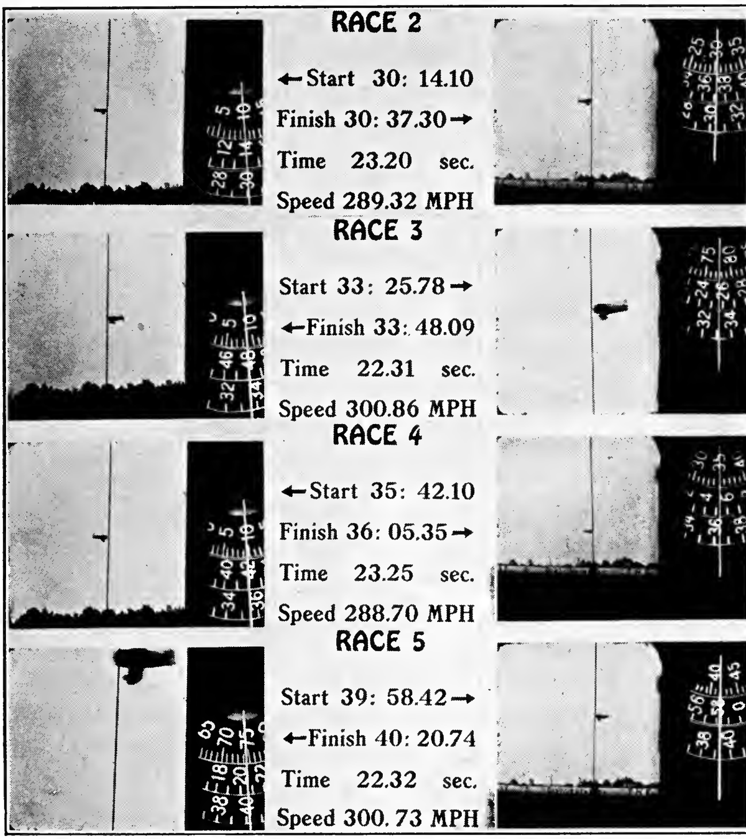



FIG. 10. Cleveland air races. 3-kilometer speed record. Major James Doolittle. Average speed (four consecutive trials) 294.90 mi. per hr.

official timing means at the Cleveland Air Races, August 28 to September 5, inclusive. In order to time a straightaway airplane speed trial, it was necessary of course to have two camera clocks operating in synchronism from one generator, one to photograph the be-

ginning, a second to photograph the finish of the race. The second camera was obtained and modified, and two camera-operated clocks were used at Cleveland. All the straight-away races in which there was any indication that a speed record might be broken were photographed.

Fig. 10 shows Major Doolittle breaking the world's record for land planes over a 3-kilometer course. These pictures are not, of course, official; but it is interesting to note that the official average speed made by Major Doolittle as determined by the official method was 294.48 miles per hour, while the speed determined by the camera clock was 294.90 miles per hour.

# A METHOD FOR THE CALCULATION OF THE CORRECT AND MOST ECONOMICAL CONCENTRATIONS OF ELON AND HYDROQUINONE IN A BORAX DEVELOPER FOR MOTION PICTURE FILM*

ALAN M. GUNDELFINGER**

**Summary.**—*Holding temperature, developing time, and agitation constant, the following relations exist: (1) In an elon-borax-sulfite developer, sulfite held constant and borax varied with the elon,* $\gamma = K \log E + C$, *where* $E$ = *elon conc. and* $K$ *and* $C$ = *constants: (2) In an elon-hydroquinone-borax-sulfite developer, hydroquinone and sulfite held constant and borax varied with the elon,* $\gamma = K \log E + C$, *where* $E$ = *elon conc. and* $K$ *and* $C$ = *constants: (3) In an elon-hydroquinone-borax-sulfite developer, elon, borax, and sulfite held constant,* $\gamma = K \log H + C$, *where* $H$ = *hydroquinone conc. and* $K$ *and* $C$ = *constants: (4) In an elon-hydroquinone-borax-sulfite developer, sulfite held constant and borax varied with the elon,* $\gamma = K_1 \log E + K_2(\log E)(\log H) + K_3 \log H + K_4$, *where* $E$ = *elon conc.,* $H$ = *hydroquinone conc., and* $K_1$, $K_2$, $K_3$, $K_4$ = *constants: (5) In an elon-hydroquinone-borax-sulfite developer,* $\gamma$ *and sulfite held constant, and borax varied with the elon, there exist optimum concentrations of elon and hydroquinone for maximum economy.*

Carlton and Crabtree[1] have stated, "If borax is added to convert the elon into the elon base, the rate of development increases with the elon concentration. The gamma produced for a constant time of development increases as a linear function of the logarithm of the elon concentration."

The purposes of this investigation were as follows:

(1) To verify the statement of Carlton and Crabtree concerning the exponential relation between elon and gamma in an elon-borax-sulfite developer.

(2) To determine whether or not the same, or any other relation, exists between elon and gamma in an elon-hydroquinone-borax-sulfite developer (hydroquinone maintained constant).

(3) To determine the relation between hydroquinone and gamma, if any, in an elon-hydroquinone-borax-sulfite developer (elon maintained constant).

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(4) To determine, if possible, the relation between gamma, elon, and hydroquinone in an elon-hydroquinone-borax-sulfite developer (elon and hydroquinone both variable).

(5) To derive a method for calculation of the most economical concentrations of elon and hydroquinone, provided that the function of gamma, elon and hydroquinone can be evaluated.

## I. LABORATORY PROCEDURE

(*a*) *Film Stock.*—In performing the series of tests for this investigation it was thought advisable to use negative stock, which reacts considerably better with borax developers and has greater latitude than positive stock, and to use one with which a fair amount of light could be used in the dark room. Consequently, Eastman orthochromatic *No. 1201–171* was chosen.

(*b*) *Sensitometric Exposures.*—Sensitometric strips were exposed on an Eastman Type II*b* sensitometer with a lamp and filter accurately calibrated, by the Eastman Kodak Co., as to intensity and color temperature (5400°K.) and a time scale in powers of $\sqrt{2}$.

(*c*) *Development.*—Development of the sensitometric strips was performed in the following manner:

Two strips were fastened, emulsion side up and adjacent to each other, to a piece of plate glass. The plate of glass was dropped, simultaneously with the releasing of a timing device, into a tray containing just sufficient developer to cover the strips. The temperature of the developer was maintained at 18° ± 1°C. Immediately after dropping the plate of glass into the developer, brushing of the strips was started. A camel's-hair brush, wide enough to cover both strips, was used, and the brushing was accomplished with a uniform reciprocating stroke of length equal to that of the strips. The rate of brushing was maintained as constant as was humanly possible. At the instant of the sounding of the time signal, indicating completion of the required development time, the glass plate with its attached strips was transferred bodily to an adjacent tray containing hypo solution, after which the strips were thoroughly washed and dried. The time of development in all cases was maintained at 5.0 minutes, and the time of hypo immersion was considerably more than sufficient for the complete removal of all undeveloped silver halide.

(*d*) *Density Determination.*—Densities on the developed sensitometric strips were determined with a Western Electric densitometer using a Bausch & Lomb head of the polarizing type. The

observations were made with the emulsion side of the strips downward, against the diffusion glass.

(*e*) *Curve Plotting.*—In plotting the H & D curves, the average density of corresponding exposures, on two strips developed simultaneously, was plotted against the $\log_{10}$ of the absolute exposure.

(*f*) *Developers.*—All developers used in this investigation contained 300.0 gm. of sodium sulfite per gallon, and a quantity of borax, per gallon, equal to the weight of elon, in grams per gallon, plus 8.0. In explanation, it might be well to call attention to the fact that since elon requires approximately an equal quantity, by weight, of borax in order to be converted into the elon base,[1] this arrangement was utilized so that a theoretical excess of 8.0 gm. of free borax

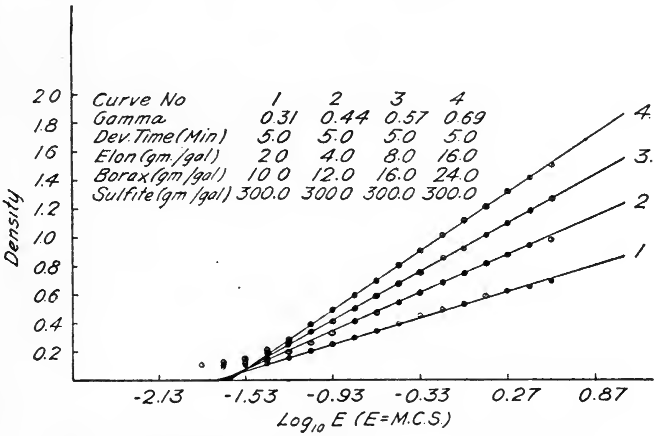


FIG. 1. H & D curves of elon-borax-sulfite developers.

would always be available to accommodate the slightly low *p*H value of hydroquinone without seriously affecting the *p*H value of the developer.

The four fundamental developers used were as follows:

| *Developers* | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Elon (gm./gal.) | 2.0 | 4.0 | 8.0 | 16.0 |
| Borax (gm./gal.) | 10.0 | 12.0 | 16.0 | 24.0 |
| Sulfite (gm./gal.) | 300.0 | 300.0 | 300.0 | 300.0 |

In addition, sixteen more developers were used consisting of each of the above-tabulated developers containing, in addition, 2.0, 4.0, 8.0, and 16.0 gm., respectively, of hydroquinone per gallon.

### II. RELATION BETWEEN GAMMA AND ELON IN AN ELON-BORAX-SULFITE DEVELOPER

Fig. 1 shows the H & D curves obtained from the four fundamental developers without hydroquinone. Fig. 2 shows the curve obtained

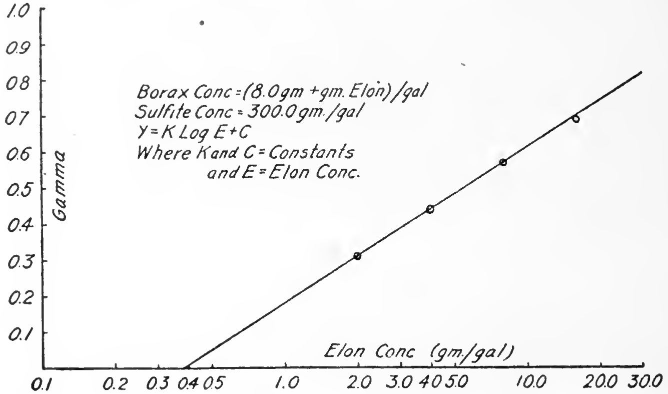


FIG. 2. Gamma *vs.* elon concentration; for elon-borax-sulfite developers.

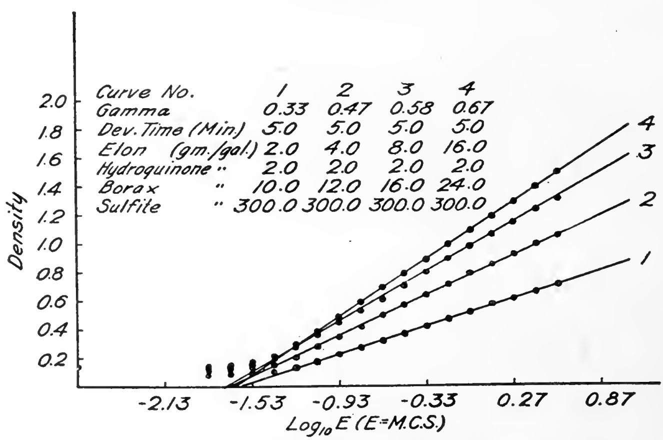


FIG. 3. H & D curves for elon-hydroquinone-borax-sulfite developers (hydroquinone, 2 gms./gal.).

by plotting gamma against log elon concentration. Examination of the curve reveals the fact that the general equation is:

$$\gamma = K \log E + C \tag{1}$$

where $K$ and $C$ = constants and $E$ = elon concentration.

Evaluating the constants of the equation for the curve best representing the data, the following equation is obtained:

$$\gamma = 0.432 \log_{10} E + 0.18 \, .$$

If, now, in equation (1), $\gamma$ is differentiated with respect to $E$, then,

$$\frac{d\gamma}{dE} = \frac{K}{E} \tag{2}$$

or the derivative or slope of the $\gamma$-elon curve is inversely proportional to the elon concentration and the proportionality constant is the slope of the $\gamma$-log $E$ curve. In other words, the rate of change of $\gamma$ with respect to elon concentration, holding temperature, agitation, and development time constant, is inversely proportional to the elon concentration.

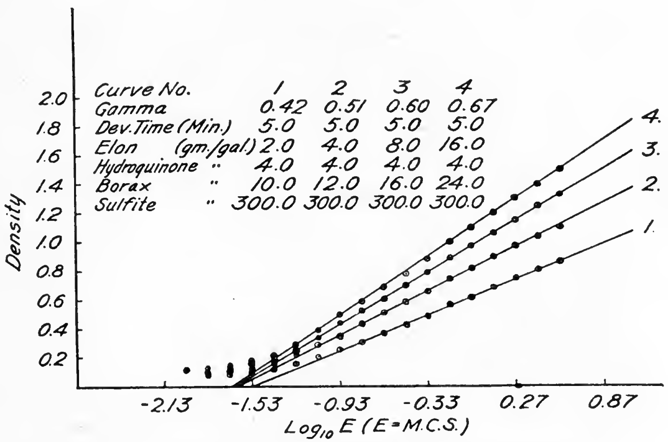


FIG. 4. Same as Fig. 3 (hydroquinone 4 gms./gal.).

### III. RELATION BETWEEN GAMMA AND ELON IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER

Figs. 3, 4, 5, and 6 show the H & D curves obtained from the four fundamental developers containing 2.0, 4.0, 8.0, and 16.0 gm. hydroquinone, respectively. Fig. 7 shows the curves obtained by plotting gamma against log $E$ in the presence of constant concentrations of hydroquinone. It can be observed quite readily that the same general relation exists between $\gamma$ and elon concentration, in the presence of a fixed concentration of hydroquinone, as exists in the absence of the latter. That relation may be represented also by equations identical to (*1*) and (*2*).

IV. RELATION BETWEEN GAMMA AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER

Inasmuch as the reaction of hydroquinone, as well as other developing agents, on the silver halide grain is primarily one of reduc-

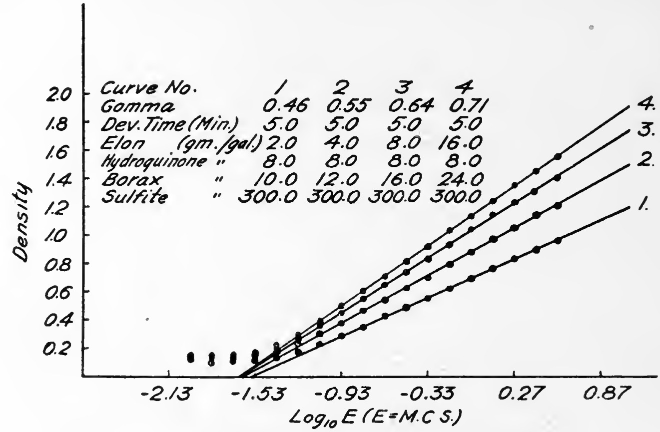


FIG. 5. Same as Fig. 3 (hydroquinone 8 gms./gal.).

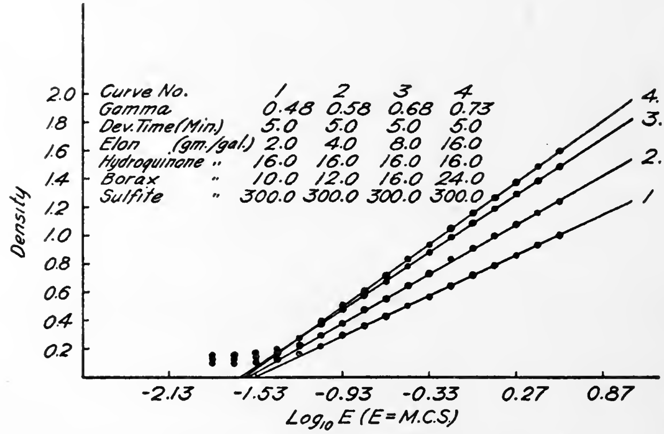


FIG. 6. Same as Fig. 3 (hydroquinone 16 gms./gal.).

tion, the mechanics of which should in all cases be similar if not exactly the same, it should be expected that the relation between gamma and hydroquinone is the same as that between the former and elon.

Fig. 8 shows the curves obtained by plotting gamma against log hydroquinone concentration, in the presence of constant concentrations of elon. The data for these curves were obtained, likewise, from those of Figs. 3, 4, 5, and 6. As was to be expected, it can be

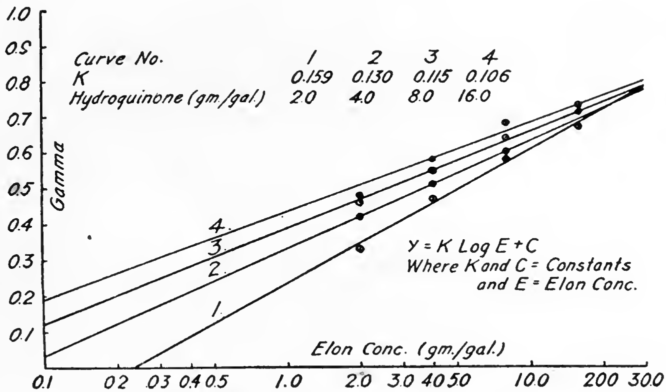


FIG. 7. Curves of gamma *vs.* log elon, for various constant concentrations of hydroquinone; data obtained from Figs. 3 to 6, incl.

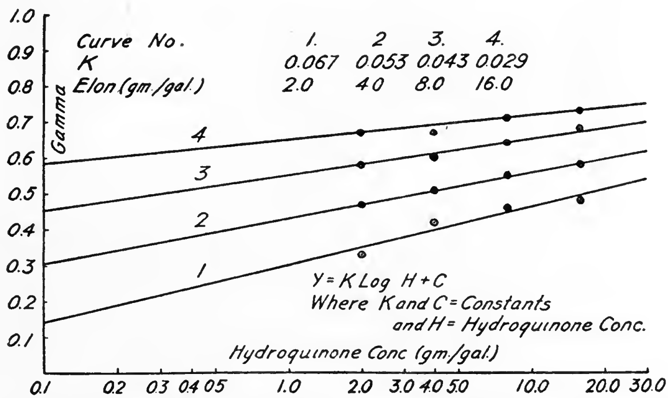


FIG. 8. Curves of gamma *vs.* log hydroquinone concentration for various constant concentrations of elon; data obtained from Figs. 3 to 6, incl.

observed quite readily that the same general relation exists between gamma and hydroquinone, in the presence of a constant concentration of elon, as exists between gamma and elon, in the presence of a

fixed concentration of hydroquinone. This relation may be represented by:

$$\gamma = K \log H + C \tag{3}$$

$$\frac{d\gamma}{dH} = \frac{K}{H} \tag{4}$$

where $K$ and $C$ = constants and $H$ = hydroquinone concentration.

### V. RELATION BETWEEN GAMMA, ELON, AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER

In parts III and IV it has been shown that, holding temperature,

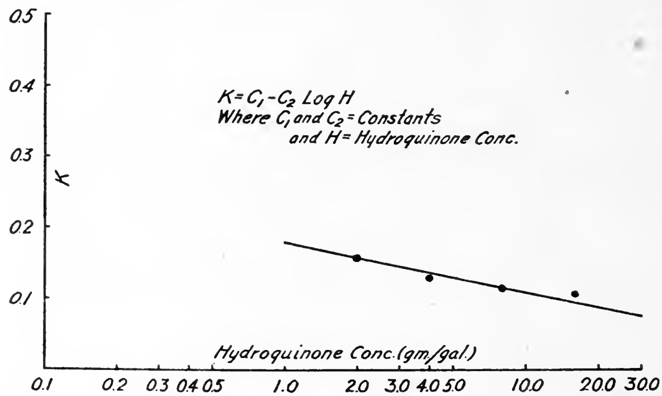


FIG. 9. Variation of the constant $K$ with hydroquinone concentration; elon-hydroquinone-borax-sulfite developers.

agitation, development time, and the concentration of the remaining constituents constant,

$$\gamma = F(E) \quad \text{and} \quad \gamma = f(H)$$

and $F(E)$ and $f(H)$ have been evaluated.

Then, if

$$\gamma = F(E, H)$$

it becomes highly desirable to evaluate $F(E,H)$.

Examination of Fig. 7 reveals the fact that $K$ of equations (*1*) and (*2*) varies with the hydroquinone concentration such that

$$K = \psi(H)$$

and equation (*2*) becomes a partial differential equation, as

$$\frac{\partial\gamma}{\partial E} = \frac{\psi(H)}{E} \tag{5}$$

Likewise, it may be observed from Fig. 8 that $K$ of equations (*3*) and (*4*) is a function of $E$, or

$$K = \phi(E)$$

such that equation (*4*) becomes a partial differential equation, as

$$\frac{\partial \gamma}{\partial H} = \frac{\phi(E)}{H} \tag{6}$$

If, then, $K$ of equations (*1*) and (*2*) is plotted against log $H$, as shown in Fig. 9, it is found that there is a linear relation between $K$ and log $H$, and $\psi(H)$ can be evaluated. Then:

$$K = \psi(H) = C_1 - C_2 \log H \tag{7}$$

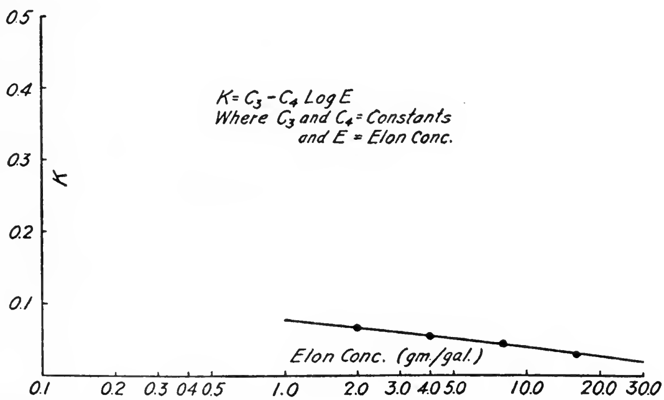


FIG. 10. Variation of the constant $K$ with elon concentration; elon-hydroquinone-borax-sulfite developers.

Similarly, $K$ of equations (*3*) and (*4*) is shown, in Fig. 10, to bear a linear relation to log $E$ such that

$$K = \phi(E) = C_3 - C_4 \log E \tag{8}$$

where $C_1$, $C_2$, $C_3$, and $C_4$ are constants.

Combining equations (*5*) with (*7*) and (*6*) with (*8*), there results

$$\frac{\partial \gamma}{\partial E} = \frac{\psi(H)}{E} = \frac{C_1 - C_2 \log H}{E} \tag{9}$$

and

$$\frac{\partial \gamma}{\partial H} = \frac{\phi(E)}{H} = \frac{C_3 - C_4 \log E}{H} \tag{10}$$

Integrating (*9*),

$$\gamma = (C_1 - C_2 \log H) \log E + f(H) \tag{11}$$

Differentiating $\gamma$ with respect to $H$ in (*11*),

$$\frac{\partial \gamma}{\partial H} = -\frac{C_2 \log E}{H} + \frac{df}{dH}. \tag{12}$$

Combining equations (*10*) and (*12*),

$$\frac{df}{dH} = \frac{C_3 - C_4 \log E}{H} + \frac{C_2 \log E}{H} = \frac{C_3 + C_5 \log E}{H} \tag{13}$$

which on integration gives

$$\begin{aligned} f(H) &= (C_3 + C_5 \log E) \log H + C_6 \\ &= C_3 \log H + C_5(\log \mathrm{E})(\log H) + C_6 \end{aligned} \tag{14}$$

where $C_6$ = constant of integration. And on combining equations (*11*) and (*14*) there results

$$\gamma = C_1 \log E + C_7(\log \mathrm{E})(\log H) + C_3 \log H + C_6 \tag{15}$$

or

$$\gamma = K_1 \log_{10} E + K_2(\log_{10} E)(\log_{10} H) + K_3 \log_{10} H + K_4 \tag{16}$$

Equation (*15*) becomes, then, the general equation for

$$\gamma = f(E, H)$$

and evaluating the constants from the experimental data, the equation for the set of conditions in this series of tests becomes

$$\begin{aligned} \gamma = 0.402 \log_{10} E - 0.114(\log_{10} E)(\log_{10} H) \\ + 0.217 \log_{10} H + 0.174 \end{aligned} \tag{17}$$

where $E$ = elon concentration in gm. per gallon and $H$ = hydroquinone concentration in gm. per gallon.

## VI. A METHOD FOR THE CALCULATION OF THE MOST ECONOMICAL CONCENTRATIONS OF ELON AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER

An analysis of equation (*15*) of part V reveals the fact that an infinite number of combinations of elon and hydroquinone will satisfy the equation for any definite gamma. The question then arises as to the optimum concentration for the two developing agents. The natural answer to that question is that combination of concentrations which will formulate the least expensive developer.

At present there is a marked difference in the prices of elon and hydroquinone, that of the former amounting to slightly over three times that of the latter. The natural impulse would lead to the conclusion, then, that the least expensive developer would include the least possible amount of elon.

Such, however, is not the case, for a glance at the slopes of the curves of Figs. 7 and 8 will reveal the fact that elon is much the more powerful reducing or developing agent. Consequently, while it is the more expensive of the two agents, a lesser concentration of it is required to produce a definite degree of development than that of hydroquinone. On the other hand, it is possible to utilize a concentration of elon which is too high for economy.

In order to illustrate this point, let the assumption be made that the costs of elon and hydroquinone are \$3.30 per pound and \$1.00 per pound, respectively, and that the desired gamma is 0.5. Then

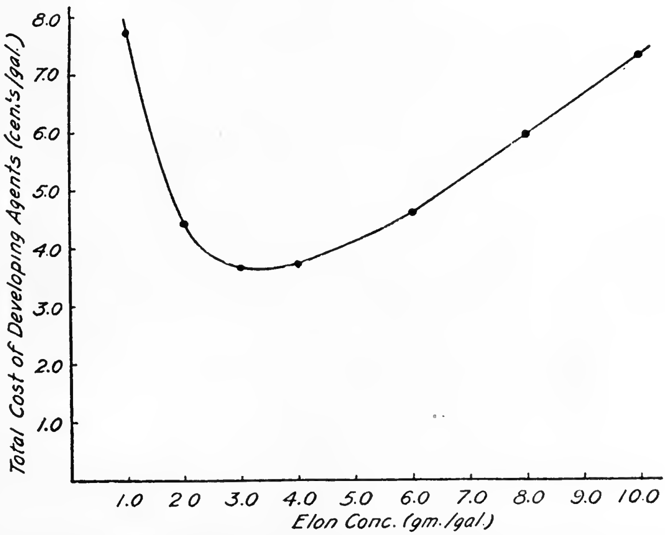


FIG. 11. Curves showing relation between total cost of developing agents and concentration of elon, for constant gamma.

by virtue of this assumption and equation (*17*), a curve (Fig. 11) has been constructed showing the relation between the total cost of developing agents per unit volume of developer and the concentration of elon.

It is apparent that the curve has a marked minimum point and that there are distinct optimum concentrations of both developing agents for maximum economy. It is perfectly possible to determine the minimum point of this curve analytically by making use of the calculus, but for all practical purposes the increased accuracy is of

no value and does not warrant the procedure, which is quite laborious.

From the curve, it is seen that an elon concentration of 3.3 gm. per gallon corresponds to the least cost of a developer which complies with the previously mentioned assumptions and is to be utilized under the precise experimental conditions of this investigation. The corresponding hydroquinone concentration is found from equation (*17*) to be 5.5 gm. per gallon.

## REFERENCE

[1] CARLTON, H. C., AND CRABTREE, J. I.: "Some Properties of Fine Grain Developers for Motion Picture Film," *Trans. Soc. Mot. Pict. Eng.*, **XIII** (1929), No. 38, p. 406.

# SOCIETY OF MOTION PICTURE ENGINEERS

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# SOCIETY ANNOUNCEMENTS

## SPRING, 1933, CONVENTION

### HOTEL PENNSYLVANIA, NEW YORK, N. Y

### APRIL 24 TO 28, INCLUSIVE

Arrangements for the approaching Spring, 1933, Convention, to be held at New York, April 24 to 28, with headquarters at the Hotel Pennsylvania, are rapidly proceeding, the plans including a number of outstanding presentations that will make it worth every one's while to be present at the meeting. Standardization is to play an important part in the proceedings. The economy trends in sound picture production and exhibition that the industry is now showing will be discussed.

The semi-annual banquet of the Society is to be held on April 26, at the Hotel Pennsylvania. An evening of pleasure and interest is promised, and all are urged to make every effort to attend.

Mr. W. C. Kunzmann, chairman of the Convention Committee, is being ably assisted in his efforts to make the Convention an outstanding success by the Local Arrangements Committee under the chairmanship of Mr. H. Griffin.

All technical sessions will be held in the *Salle Moderne*, on the roof of the Hotel Pennsylvania. Registration will be opened at 9 A.M., Monday, April 24. The registration fee will be $3, and the banquet charge $4.50.

Plans are being made to assist out-of-town visitors to the Convention to pass an interesting time while in New York, and special film programs and trips of interest will be arranged. Final details of the program, including hotel rates and other pertinent information, will be mailed to the members of the Society at a later date. Members and friends of the Society are urged to make every effort to attend the Convention.

## EXHIBIT OF NEW MOTION PICTURE APPARATUS

### SPRING, 1933, CONVENTION

Arrangements are being made to hold an exhibit of newly developed motion picture apparatus, in order to acquaint the members of the Society with the newly devised tools of the industry. This exhibit will not be of the same nature as the usual trade exhibit. There will be no booths, although each exhibit will be allotted definite space, and all exhibits will be arranged in one large room. The following regulations will apply:

1. The apparatus to be exhibited should be new or have been developed or improved within the past 12 months.

2. Each exhibitor will be permitted to display a card giving the name of the manufacturing concern, and each piece of equipment shall be labeled with a plain label free from the name of the manufacturer.

3. A technical expert capable of explaining the features of the apparatus exhibited must be present during the period of the exhibition.

4. A charge for the exhibit will be made in accordance with the space occupied, as follows: up to 20 sq. ft., $10.00; 20 to 30 sq. ft., $15.00; 30 to 40 sq. ft., $20.00; 40 to 50 sq. ft., $25.00.

Please direct requests for space to the General Office of the Society, 33 West 42nd St., New York, N. Y., stating the number and nature of the items to be exhibited.

## ARRANGEMENTS PROGRAM

### SPRING MEETING OF THE SOCIETY, HOTEL PENNSYLVANIA, NEW YORK, N. Y.

### APRIL 24–28, 1933, INCLUSIVE

### COMMITTEES IN CHARGE OF ARRANGEMENTS

#### NEW YORK LOCAL COMMITTEE

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H. RUBIN
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T. E. SHEA

#### CONVENTION REGISTRARS

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E. R. GEIB
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S. R. RENWICK

#### HOSTESS TO CONVENTION

MRS. E. I. SPONABLE
*assisted by*

MRS. O. M. GLUNT
MRS. M. C. BATSEL
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| | |
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| JAMES FRANK, JR. | G. C. EDWARDS |
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Officers and Members of Projectionists Local No. 306, I.A.T.S.E., New York.

### MEMBERSHIP

H. T. COWLING, *Chairman*

### PRESS AND PUBLICITY

W. WHITMORE, *Chairman*

### CONVENTION SESSIONS

All technical sessions and film exhibitions will be held in the *Salle Moderne,* Roof Garden, Hotel Pennsylvania, where also will be located the registration headquarters. A meeting room will be provided for the Board of Governors and the technical committees in the Roof Garden, off the entrance to the *Salle Moderne.*

### LADIES' HEADQUARTERS

A private parlor suite on the 17th floor of the Hotel Pennsylvania, directly beneath the Convention Headquarters, will be reserved for the use of the ladies.

### BANQUET AND DANCE

The S.M.P.E. Semi-annual Banquet and Dance will be held in the Grand Ball Room of the Hotel Pennsylvania, Wednesday evening, April 26, at 7:30 P.M.: an evening of dancing and entertainment—no banquet speeches.

Banquet tickets should be obtained at the registration headquarters; tables reserved for 8 or 10 persons.

Excellent accommodations are assured by the Hotel Pennsylvania, and minimum rates are guaranteed. Room reservation cards should be returned immediately to the Hotel Pennsylvania in order to assure satisfactory reservations. Those who will motor to New York will be granted special daily and weekly car storage rates at the modern fire-proof garage adjoining the hotel.

The hotel management has arranged for golfing privileges for members at the Lido Country Club, Lido Beach, Long Island; the Salisbury Country Club, Westbury, Long Island; and the Queens Valley Golf Club, Inc., Forest Hills, New York.

### NEW APPARATUS EXHIBIT

The exhibit will be held in the Roof Garden of the hotel, adjacent to the registration headquarters. Please communicate with Mr. S. Harris, Editor-Manager, at the General Office of the Society, 33 West 42nd Street, New York, N. Y., regarding space and exhibit regulations.

## TENTATIVE PROGRAM

### MONDAY, APRIL 24

The morning will be devoted to organization of the convention, registration of members, and meetings of committees. An informal luncheon for members, guests, and friends will be held in the Roof Garden of the Hotel Pennsylvania at 12:30 P.M. Several addresses will be delivered by prominent speakers.

Luncheon tickets should be obtained at the registration desk and will be collected at the tables. Don't fail to attend.

**2:30 P.M.** *Salle Moderne.*

Convention called to order.
Address by President A. N. Goldsmith.
Report of the Secretary, Mr. J. H. Kurlander.
Report of the Treasurer, Mr. H. T. Cowling.
Convention Announcements, Mr. W. C. Kunzmann.
Papers Committee, Mr. O. M. Glunt, Chairman.
Technical papers program.

**8:00 P.M.** *Salle Moderne.*

Interesting program of recent talking motion pictures. (Admission by registration card.)

### TUESDAY, APRIL 25

**9:30 A.M.** *Salle Moderne.*

Technical papers program.

**2:30 P.M.** *Salle Moderne.*

Technical papers program.

**8:00 P.M.** *Bell Telephone Laboratories.*

Lecture and demonstration by Dr. H. E. Ives. Tickets for this session will be supplied by the registrars. The laboratories are located at 463 West Street, New York, N. Y.

WEDNESDAY, APRIL 26

**9:30 A.M.** *Salle Moderne.*
Technical papers program.

**1:00 P.M.** This afternoon is left open for recreation.

**7:30 P.M.** *Grand Ball Room,* Hotel Pennsylvania.
S.M.P.E. Semi-annual Banquet. Dancing and entertainment. No banquet speeches.

THURSDAY, APRIL 27

**9:30 A.M.** *Salle Moderne.*
Technical papers program.

**2:30 P.M.** *Salle Moderne.*
Technical papers program.

**8:00 P.M.** *Salle Moderne.*
Popular talk and motion picture program. (Admission by registration card.)

FRIDAY, APRIL 28

**9:30 A.M.** *Salle Moderne.*
Technical papers program.

**2:30 P.M.** *Salle Moderne.*
Technical papers program.
Open Forum and Convention Adjournment.

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*Papers Committee*
O. M. GLUNT, *Chairman*

*Convention Committee*
W. C. KUNZMANN, *Chairman*

## NEW YORK SECTION

The monthly meeting of the New York Section was held on March 8 in the auditorium of RCA Photophone, Inc., at New York, N. Y., approximately one hundred and twenty members and guests attending. Mr. M. C. Batsel, director of the Photophone and Applications Division of the RCA Victor Co., described briefly the development and application of the new RCA high-fidelity recording and reproducing equipment.

Following his address, a number of short and feature pictures were reproduced, in order to exemplify the improvements achieved by the new system. The Walt Disney release, *Santa Claus in Toyland,* a Mickey Mouse short, and a Van Beuren animated cartoon, recorded with high-fidelity equipment, were reproduced. Following these short reproductions, an RKO feature picture entitled *Our Betters,* starring Constance Bennett, and recorded on the RCA type *PR-4* variable width recorder (described in the March, 1933, issue of the JOURNAL) equipped with a special high-frequency response galvanometer, was projected and reproduced. The galvanometers used for recording, devised by Mr. C. Dreher, were designed to have an approximately linear response at frequencies up to 8000 cycles.

A general discussion of the equipment and the reproduction, from the standpoint of recording and reproducing sound, followed the demonstration; after which the recording and reproducing equipment installed in the auditorium were opened to inspection by the members, and were ably described by members of the RCA Photophone organization.

Unusual interest was shown by the audience in the new equipment and in the technical endeavors being made to improve the quality of recording and reproducing; and that this interest was real and that the meeting was quite successful were attested to by the fact that nearly the entire audience remained until the adjournment, which occurred unusually late.

D. HYNDMAN, *Secretary-Treasurer*

## PACIFIC COAST SECTION

The second meeting of the season was held in the theater of Paramount Productions, Inc., approximately one hundred and twenty-five members and guests attending. This meeting emphasized further the plans of the present Board of Managers to depart from the usual style of meeting dealing primarily with motion pictures as a means of entertainment. Although the importance of the motion picture is admittedly greatest in the entertainment field, other fields, including those of advertising, history, education, *etc.*, are developing so rapidly that the professional motion picture engineer is obliged to take cognizance of their requirements and technological needs. That excursions into these fields are deemed worth while is attested to by the attendance at the meeting and the amount of interest displayed.

Mr. J. Dubray had been appointed chairman of the Program Committee for this meeting, and had ably arranged for a session devoted to the application of motion pictures by the medical profession. A business appointment unfortunately preventing Mr. Dubray from attending the meeting, Dr. D. MacKenzie kindly consented at the request of Section Chairman E. Huse to act as chairman of the meeting, in which capacity he ably kept up the spirits of those viewing the pictures who were unaccustomed to witnessing six-inch close-ups of human interiors.

The program opened with the projection of a two-reel picture of an appendectomy, in 35-mm. Technicolor, followed by another showing the removal of a breast cancer; both operations having been performed by Dr. M. Kahn, of the Cedars of Lebanon Hospital. These pictures were of particular interest in that they had been photographed by a professional cameraman, Mr. H. Green, under the supervision of a commercial producing company.

There were also projected two reels of a picture dealing with plastic surgery, the work of Dr. H. L. Updegraf, also of the Cedars of Lebanon Hospital, in 35-mm. Magnacolor; followed by a 16-mm. film depicting the complete case history of the reconstruction of a burned face. The skill shown in this work, which involved fourteen operations over a period of as many months, evoked a genuine response of admiration from the audience. Dr. Updegraf's exhibition was accompanied by an explanatory talk that left little doubt in the minds of the spectators as to the value of this kind of application of motion pictures.

Two reels of 16-mm. film illustrating the technics of cystectasy and prostatec-

tomy, were exhibited by Dr. E. Belt, who accompanied the projection with a description of the surgery and the methods employed in obtaining the pictures.

Dr. J. C. Irwin screened about 1000 feet of 16-mm. film showing three examples of Cæsarian section. An interesting feature of this showing was the progress that had been made in the photography of the three successive operations.

Dr. Lozier, of the University of Southern California, closed the exhibit with a screening of dental films, demonstrating the advantages of superspeed panchromatic negative film over the orthochromatic stock used some years ago.

At the invitation of the chairman, the members of the section were addressed briefly by Mr. W. C. Kunzmann, vice-president of the Society. Mr. Kunzmann voiced the appreciation of the Board of Governors and the officers of the Society for the great activity being shown by the Pacific Coast Section.

The large attendance and the great amount of interest shown in the subject of the meeting were very gratifying, indicating that fields of application of motion pictures not frequently explored hold for the motion picture engineer many features of technical and general interest.

G. RACKETT, *Secretary-Treasurer*

## SUB-COMMITTEE ON SCREEN BRIGHTNESS AND THEATER ILLUMINATION

Several meetings of representatives of the several projection committees have recently been held for the purpose of studying the various problems involved in measuring, and in arriving at recommendations for, the brightness of projection screens and the illumination of theater auditoriums.

Upon invitation of the S.M.P.E., a committee was established by the Illuminating Engineering Society, under the chairmanship of Prof. S. R. McCandless of Yale University, for the purpose of collaborating with the S.M.P.E. group. The latter was consequently officially organized, under the name given above, as a subcommittee of the Projection Screens Committee. The personnel of the sub-committee follows:

S. K. WOLF, *Chairman*

A. C. HARDY (*Chairman*, Projection Theory Committee)
W. F. LITTLE (*Member*, Projection Screens Committee)
H. RUBIN (*Chairman*, Projection Practice Committee)
H. B. SANTEE (*Chairman*, Sound Committee)

## PROJECTION PRACTICE COMMITTEE

At a meeting held on March 15, at New York, N. Y., a draft of the report to be presented at the convention in April was read to the Committee by Chairman Rubin, for discussion and revision. The report describes the special test reels that have been developed by the Committee, mentioned in previous issues of the JOURNAL, and a special tool that has been devised for the purpose of aligning the arc lamp with the optical axis of the projector; and discusses various problems incident to change-over marks and their location, and positive print density and studio screen illumination.

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National Carbon Co.
RCA Victor Co., Inc.

## HONOR ROLL
### OF THE
## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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*CONTENTS*

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SYLVAN HARRIS, EDITOR



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Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

# AN INTRODUCTION TO THE EXPERIMENTAL STUDY OF VISUAL FATIGUE*

PETER A. SNELL**

**Summary.**—*Previous work has shown that fatigue of the visual process as a whole is not directly measurable; it is therefore necessary to adopt the alternative method of studying the individual processes involved in vision. An analysis of the studies so far made on these unit functions shows that the motor processes involved are not readily fatigued; ineffective activity of these processes, however, rapidly leads to sensations of fatigue. This activity results from inadequate sensory projection, whether the inadequacy is a result of difficult external seeing conditions or of decreased efficiency of the retinal processes. Experiments were performed which showed that: (1) the effective intensity of a given stimulus was affected considerably by the previous activity of the retina; (2) contrasts, and especially flicker, produced a marked retinal fatigue; (3) the site of this fatigue lay in the retinal structures behind the sense endings rather than in the sense endings themselves. It is concluded that retinal fatigue contributes a larger factor to visual fatigue than has hitherto been supposed; as long as the visual task is such that the factors producing a decrease in retinal efficiency are minimal, as is not usually the case in viewing the motion picture, visual fatigue will not supervene with unusual rapidity.*

At the very beginning of a consideration of the problem of visual fatigue, it is apparent that no solution will be forthcoming until after a prolonged attack by many investigators. The amount of work that can be accomplished in one year is small compared with what is yet to be done. Whatever progress can be made in this short interval of time is valuable only in proportion to the amount of solid foundation laid for the benefit of those who will continue toward the solution. In order to proceed on a fundamental basis, therefore, this study was begun and carried out along three related lines: (*1*) a partial compilation of the studies so far made on visual fatigue; (*2*) an analysis of some recent advances in the field of visual physiology which are pertinent to this study; (*3*) the undertaking of experimental work leading to the establishment of new facts aiding in the further elucidation of the problem.

It is obviously desirable to agree on a meaning for the term fatigue.

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** S. M. P. E. Fellow at the University of Rochester, Rochester, N. Y.

To the layman fatigue implies the idea of physical tiredness, usually the result of work, and includes in its connotation loss of efficiency and lack of desire. In this sense the term is too broad for our purpose. In strictly physiological nomenclature, fatigue has a much more definite meaning. This meaning is expressed in the following rather technical definition: "Fatigue is a metabolic state resulting from the inability of anabolic processes to proceed as rapidly as catabolic ones during the activity of an organ or part." This definition puts fatigue definitely with the phenomena peculiar to living tissues, draws attention to fatigue as a state apart from any other state or situation of such tissues, and emphasizes the role of activity in the establishment of the state. The definition properly omits reference to the manifestations of fatigue, as they are rather characteristic of the particular organ subject to fatigue than of the state itself.

We can not consider fatigue without reference to the phenomenon of adaptation. The above definition of fatigue is also a definition of adaptation. One can consider that in the case of adaptation the catabolic reaction is desirable; in the case of fatigue, it is undesirable. It seems that nature has made the best of the situation, and upon occasions has turned the occurrence of the fatigue reaction to a useful purpose. Adrian[1] distinguishes somewhat more definitely between the two in describing fatigue as a "decline in activity caused by the previous activity of the organ," and adaptation as a "decline in excitability caused by the stimulus—the change in the environment—quite apart from the existence of activity." This definite distinction is not applicable to any situation, however, since in general the state of any organ at a given time is inseparably linked up both with its previous activity and with the stimulus existing at that time.

Actually, there are characteristic differences between fatigue and adaptation. (Hereafter in this discussion fatigue refers to physiological fatigue.) Adaptation is a reaction which occurs immediately following the presentation of the situation calling for it, takes place rapidly, brings about a benefit to the organism, and, finally, has a slight, if any, subjective effect upon the organism. Fatigue, on the other hand, is delayed in its occurrence following the presentation of an adequate stimulus, is slow to develop, brings about harm to the animal economy, and, finally, has a rather profound effect upon the organism. Yet, in spite of these differential characteristics, fatigue

and adaptation can not be definitely and quantitatively differentiated in any given set of conditions.

Ophthalmologists as a group are outstanding in contributions to the study of the problem of visual fatigue, since they are in a position to recognize its importance as well as to observe the sequence of cause and effect in its occurrence. In his practice the ophthalmologist sees cases representative of the whole range of fatigue states, from the simplest so-called "eye-strain" to the severe crippling condition of asthenopia. If we examine this whole range of conditions, we find that the differences between them are almost entirely those of degree. Asthenopia, according to Jackson,[2] refers to the condition present in "those unable to use the eyes for more than a very brief time without pain, although the eyes are without recognizable ocular conditions to account for this disability." The pain, hyperemia, lacrymation, and other symptoms and signs present in this condition, are the same in nature and sequence as those present in cases of eye-strain due to a simple refractive error or any other cause. Lancaster's[3] description of the symptoms and signs occurring as a result of ocular work under faulty illumination is practically the same as Jackson's[4] account of those manifesting the existence of visual fatigue. There is no doubt that the eye always responds by the same fatigue reaction to any and all conditions under which, as Lancaster has shown, seeing is a more difficult task than the visual mechanism is prepared to handle.

Anything causing difficult seeing will result in eye-strain. In the production of visual fatigue under conditions for seeing which are not unfavorable, it is the decline in efficiency of the eye after a fairly prolonged period of use which brings about the condition of difficult seeing resulting finally in eye-strain. If the eye or visual apparatus is exceptionally poor, average conditions for seeing are too difficult for the eye to handle from the start, and eye-strain appears after a very short exposure. If the external conditions for seeing are unfavorable, even though the eye is normal or average in ability, eye-strain will result after a fairly short interval. Luckiesh and Moss[5] have emphasized this relationship between the external and the physiological factors in ocular function by the consideration of seeing as "a partnership of lighting and vision."

Eye-strain which has progressed far enough to be causing subjective symptoms has become truly severe. Jackson[4] has emphasized the fact that headache and eyeache indicate the establishment

of a pathological reaction rather than temporary weariness. "Normal visual fatigue rarely rises into consciousness. Only when the organism in response to long continued or repeated excessive fatigue has developed a method of translating this into discomfort or pain does it develop into symptoms that bring patients to us for relief."

Herein lies the difficulty in finding an easy approach to the study of this problem. We can not tell when a normal state of fatigue has been produced, because we are not immediately conscious of its presence nor are we conscious of the increasing effort necessary to counterbalance it. Many attempts have been made to demonstrate the occurrence of normal visual fatigue by following the changes in time necessary to perform a given task after a preliminary variable fatiguing period, or by following changes in external conditions necessary to keep the eyes working at a given pace. Some of these experiments are extremely interesting. Luckiesh and Moss[5] cite an experiment in which the time required to read a given amount of printed matter when the page was stationary was compared with that required when it was vibrating. The experiment showed that although subjectively the task was quite obviously more difficult when the page was vibrating, nevertheless the time consumed was practically the same in both cases. Ives,[6] in another experiment, found that there was little change in visual acuity following prolonged visual work under poor as compared with good lighting conditions. In a different type of experiment, involving a visual task which called for prolonged use of the extraocular muscles, Cobb showed that the ability of the subject to perform the task did not change when a high illumination level was substituted for a low one, although the task set elicited a severe visual fatigue.

Luckiesh and Moss[5] have suggested that the failure to demonstrate visual fatigue by these methods is due to the biological principle of compensation. After fatigue, the body or any part of it can still perform a given task as quickly and as accurately as before; because it has the faculty of drawing on reserve forces only when reserves are needed, and of conserving any energy remaining so that it will be available for the continuance of response at the previous level. The occurrence of visual fatigue is accompanied by greater difficulty in seeing, not by less ability to see.

It is evident that the demonstration and quantitative measurement of visual fatigue offers an unusually complicated problem.

It is possible to recognize the presence of visual fatigue, and to state with some degree of certainty the conditions under which it is likely to occur. It is not yet possible to explain how it is produced, what factors underlie its occurrence, what the vulnerable points in the visual mechanism are, nor how these points may be reached or protected. In order to increase our knowledge concerning these important questions, the prime requisite for experimental attack is a method of measuring visual fatigue. And up to the present time this phenomenon has taken very unkindly to association with any form of yardstick.

Since visual fatigue as a whole appears at present impossible of measurement, the only alternative open is the measurement of the fatigue of the various individual processes involved in vision. The physiological characteristics and properties of the different tissues have been carefully studied, and their behavior is fairly well known. It should be possible, therefore, by determining the reactions of the individual units or unit functions to fatiguing conditions, to determine the locations, and the relative amounts of fatigue in those locations, and their proportions to the sum total of visual fatigue.

The first step in such an attack is therefore the subdivision of the visual process into its unit functions and structures. The accompanying classification has been adopted as a basis for the study of the various parts of the visual mechanism as they individually show themselves subject to fatigue.

The responsibility for visual fatigue has been laid at the door of most of the functional groups enumerated above. Many of these groups have been studied experimentally, and a large amount of interesting and important data relative to the occurrence of fatigue has been accumulated. A study of the results of those experiments becomes an integral part of our immediate problem, since it is to those findings that we must add further experimentation in order to increase the factual basis leading to the solution of our problem.

A very prevalent idea among workers on the subject is that the extraocular muscles are the chief offenders in the establishment of visual fatigue. A moment's consideration will bring out the fact that the eyes are in motion almost constantly throughout the day, and that no matter what the occupation, they are an important and ever-active tool. Luckiesh and Moss[5] have estimated that one-fourth of the consumption of bodily energy is due to seeing. The number of motions made by an eye in an average day's work is of

course tremendous. On the other hand, the average amount of motion performed by the eye does not result in sufficient fatigue to produce perceptible symptoms. One is very conscious, for example, of fatigue of the upper arm muscles when an attempt is made to hold the arms outstretched for even a short length of time. In all probability, the eye muscles are of sufficient strength to care for the average needs of ocular motion without becoming fatigued. It is necessary, however, to examine this question much more care-

**THE VISUAL PROCESS**

| *Functional Group* | *Function* | *Anatomical Structures* |
|---|---|---|
| *1.* Effectors—the mechanisms controlling change in the physical modification of the incident light and its relation to the eye. | *a.* Accommodation (lens changes only). | Ciliary body musculature. |
| | *b.* Diaphragmatic function of the iris. | Iris, constrictor, and dilator muscles. |
| | *c.* Fixation. | Extraocular muscles. |
| | *d.* Pigment migration. | Hexagonal cells of the retinal epithelium. |
| | *e.* Movements of cones and rods. | Cones and rods. |
| *2.* Receptors—the mechanisms bringing about the transposition from physical to physiological stimulus. | *a.* Irritability to light. | Rods and cones. |
| *3.* Conductors—the mechanisms involved in the conduction of the physiological stimulus, and its elaboration to the condition of perception. | *a.* Conduction and perception. | Retina (except rods and cones), optic nerve, and brain. |
| | *b.* Control and conduction of the stimulus for the improvement of perception through the effectors of group *1*. | Various cranial nerves and brain centers. |

fully in order to decide with some degree of probability what percentage, if any, of visual fatigue is due to fatigue of the extraocular muscles.

Lancaster[3] presents an analysis of the work done by the extraocular muscles. He points out that they are much more favorably situated in regard to their mechanical advantage than are the other striated muscles of the body. He has calculated that the amount of force required to move the eye through an arc of 10 degrees in

0.04 second is equal to 1.73 grams. The power of the muscle to overcome this load is equivalent to 750–1000 grams, so that there is a tremendous latitude between reserve force and actual demand. It is difficult to fatigue any muscle unless it is made to work against a load which is severe. While there are no direct studies as yet upon extraocular muscles, it is highly probable that such a study would show no measurable fatigue of these muscles under a load considerably greater than their average load. Under normal conditions the extraocular muscles maintain their activity indefinitely, by a mechanism whereby the various fibers in a muscle take turns supporting the load so that each individual fiber works for but a small fraction of the time; thus fatigue does not occur.

The function of the extraocular muscles is that of fixation. Lancaster[3] believes that fixation is one of the two functions in the visual process which are subject to fatigue. The process of fixation, however, involves other structures as well as the extraocular muscles, which serve only as effectors. Even if it be possible to justify the argument against the occurrence of fatigue in the extraocular muscles, there still remains the possibility of its occurring in the central mechanism controlling fixation.

By photographing the eye movements, the process of fixation has been shown to take place in two stages: first, the eyes move rapidly to bring the object being fixated in the center of the field; then, secondly, slow, delicate movements are made to bring the image of the object fixated in the exact spot upon the retina where it is wanted. During prolonged fixation upon an object, there is a constant slight shifting necessary for the finest perception possible; occasional gross movements also occur at intervals as fixation is maintained.

From a binocular point of view, fixation has a latitude which is dependent upon Panum's area. Lancaster[3] has shown that in favorable conditions, as in fixating objects which are easy to see, the eye does not make the finest adjustments of which it is capable. The ordinary adjustments required of the eyes are not very accurate. However, when conditions are unfavorable for seeing, as with poor print, unsteady light, or shiny paper, the eye must adjust more accurately in order to see as well. There is then a greater demand on the mechanism for fixation, and it is certainly possible that under these conditions the extraocular muscles as well as the mechanism for fixation may contribute to ocular fatigue.

Ferree has offered the suggestion that light striking the periphery

results in a stimulus tending to bring about fixation of the light source, with consequent turning of the eyes in that direction. If the light persists in the periphery during continued fixation of the former object, the rivalry resulting between the two fixation positions is a cause for the production of fatigue of the extraocular muscles. Such a situation frequently arises. It is, however, rather more in line with usual physiological behavior to place the site of a fatigue arising as the result of such a situation in the central mechanism for fixation, rather than in the extraocular muscles themselves. The rivalry which occurs is central; the muscles can not be fatigued by the possibility of activity which actually does not occur.

Howe[7] has made a study of fatigue of the extraocular muscles by an instrument which he calls the ophthalmic ergograph. This instrument consisted essentially of a variable prism whose strength was automatically recorded. It was found that the strength of the prism which the various muscles could overcome by their action decreased during successive attempts over a given length of time. Experiments such as these are interesting in showing the amount of effort necessary to elicit fatigue; they do not localize the site of that fatigue. If the prism is so arranged that, for example, adduction is shown to become fatigued, this fatigue may occur either in the adductor muscles, or in the central mechanism for their control, and in the mechanism for fusion of the two images. By the nature of the experiment, none of these possibilities are excluded.

It is justifiable to conclude that the evidence so far presented indicates that fixation plays only a small role in general visual fatigue, and that it is the central or nervous part of the mechanism, rather than the extraocular muscles themselves, which is the vulnerable spot in the fixation process.

Accommodation has frequently been accused of much responsibility in the occurrence of ocular fatigue. It is common knowledge that those who are inclined to suffer following visual overwork frequently lay the blame on reading and other forms of close work, which differ from distance vision in the necessity for prolonged accommodation. Accommodation, therefore, appears directly responsible. According to the generally accepted theory regarding the mechanism of accommodation,[8] the ciliary muscle is under a greater tension when the surface of the lens is adjusted to bring the image of near objects to a focus upon the retina; it is more relaxed, or under less tension, when the eye is accommodated for far objects.

This condition has led students of the problem to consider seriously the possibility that prolonged accommodation for near objects can be fatiguing on account of the prolonged increased tension which must necessarily be maintained by the ciliary muscle. In connection with accommodation, the convergence of the eyes for binocular vision introduces the problem of fatigue of the extraocular muscle system into this question.

Berens and Stark[9] made an excellent study of accommodation fatigue using an improved form of ergograph. Their findings, contrary to those of Howe, indicated that it was not usual to observe recession of the near point and decrease in amplitude of excursion within the time limit used. These experiments are extremely interesting in that they show that under much more severe use than is customary, the mechanism for accommodation does not break down. It is not unlikely, however, that within this mechanism the principle of compensation is responsible for failure to demonstrate a breakdown. It is a well-known fact that the ciliary body is overdeveloped in eyes whose refraction is hyperopic, and that in these people eye-strain is a fairly common complaint; on the other hand, individuals with myopic eyes, which have an underdeveloped ciliary body, seldom complain of ocular pain. The association of these facts can not be interpreted otherwise than as an indication that the mechanism of accommodation and the ciliary body are far from blameless in the production of ocular fatigue.

The diaphragmatic function of the iris enters into the process of accommodation. The narrowing of the pupil in this connection has for its purpose the improvement of the image by cutting off the rays from the peripheral and less perfect regions of the refracting media. It is a point of interest that this constriction of the pupil is at the same time deleterious to the accuracy of the image because of the proportionate increase in the amount of diffraction occurring around the margins of the pupil. Cobb[10] has shown that at a pupil diameter of about 4 mm. the eye is at its maximum optical accuracy.

There are so many unknown quantities in connection with accommodation that it is far too early to estimate with any degree of probability its proportion of responsibility in visual fatigue. The variables of lens changes, iris activity, and convergence function, not to mention some unsolved questions concerning the mechanism for bringing about the lens changes, all contribute to the difficulty of an attack upon the problem.

Accommodation, moreover, can not be ruled out of motion picture fatigue on the ground that near vision is not involved, since hyperopia is such a common refractive error of mankind. In general, however, the conditions present in the theater are such that very little is demanded of accommodation. Therefore, although it is impossible at present to make any really reasonable prediction about accommodative fatigue, it is justifiable to adopt for the present purpose the assumption that fatigue from accommodation is not important in ocular fatigue resulting from viewing the motion picture.

The diaphragmatic function of the iris in controlling the amount of light reaching the retina is next to be considered. It is the experience of every one that on passing from a dark environment out into the much brighter sunlight, a rather severe, sharp ocular pain occurs. Dr. Fuchs was interested in the part which the iris mechanism might play in this reaction; he performed the experiment of comparing the sensations experienced upon passing from the dark into brilliant light when his pupils were dilated with scopolamine and when they were not under the effect of the drug. In the former case he found that no pain was experienced in spite of the fact that much more light reached the retina; he logically attributed the difference in sensation to the fact that the pupil did not react when under the influence of the drug, and concluded that it was the violent contraction of the pupil which was responsible for the pain experienced. This is an extremely interesting observation. The fully contracted pupil is obviously not painful; no pain is experienced once the adaptation to the most brilliant sunlight is complete. What is it then that is painful?

Michaelson[11] has presented in connection with an analysis of 100 cases of ocular headache, a discussion of the nervous innervation of the iris and ciliary body. He has pointed out an analogy between this system and that of various other organs in the body which are grouped together by Head[12] as visceral-sensory mechanisms. Michaelson comes to the conclusion that ciliary headache is the chief type of ocular headache, and that the structures involved are analogous to those which give rise to referred visceral pain in other parts of the body. In the production of visceral pain, distension is, in practically all cases, the adequate stimulus. It is natural, therefore, to assume distension as the adequate stimulus for ciliary pain. The analogy, however, is not perfect. The pupil is not distended when

dilated; it is under conditions exactly resembling distension when, dilated, it is receiving stimuli for contraction. From Dr. Fuch's experiment it is evident that these are exactly the conditions which produce pain. It is justifiable to suspect the occurrence of perhaps less conscious visceral-sensory pain stimuli under any condition which involves the production of stimuli for decrease in pupillary size or contraction of the ciliary muscles. In general, any condition leading to increased difficulty in seeing involves the production of stimuli for ciliary activity and pupillary constriction in order to improve the image; consequently, difficult seeing becomes by this mechanism an adequate stimulus for the causation of ocular discomfort and pain.

The above considerations lend themselves in part to experimental verification. Using a method similar to that of Reeves,[13] it should be possible to study the relationship of pupillary changes to difficult visual conditions. I hope shortly to be able to undertake such a study.

Pigment migration and movements of rods and cones can be grouped together under the statement that it is not known how important a role these functions play in whatever part of the visual process they may be concerned. The chief function of these movements is probably concerned with the adaptation of the retina to different brightness levels. Arey[14] has made some studies on the question of control of pigment migration, and has found that in some animals it is easy to demonstrate a central nervous control of the activity, while in other cases the demonstration is not so easy. The significance of the movements is also not well understood. Arey interprets them as protoplasmic responses to definite stimulating agents. With the mechanism and purpose of these functions so much in doubt, consideration of them must necessarily be postponed. If they play any part in visual fatigue the magnitude of their share can not be estimated.

The question of retinal fatigue is one which has until recently not received much consideration by investigators. Its importance, however, has not been unrecognized. Jackson[4] says, "Fatigue of the retina and visual centers is more important than all other functions connected with vision." There has as yet been no direct attempt made to measure retinal fatigue, but there are numerous instances in the literature of fatigue of the retinal and central type occurring in the course of a study upon some phase of the visual

process. Luckiesh and Moss[15] cite an experiment in which the rate of working was measured when the visual task set involved a frequent change from light of one intensity to that of another. The experiment brought out the loss in work done incident to the time required for the frequent readaptation, and incidentally demonstrated that such a situation was productive of a severe eye fatigue as experienced by the subjects.

It is a well-known fact that contrasts are fatiguing. Jackson[4] believes that contrast is one of the most important sources of fatigue, and states that "retinal-central fatigue is increased by great difference in intensity of stimulus to which adjoining parts of the retina are subjected." Contrast is a phenomenon involving many factors, including not only external conditions, but also sensory, retinal, and central nervous system functions. Granit[16] has recently pointed out that there is a retinal component in contrast, and thereby has added a further indication toward the probability that the effect of contrast in producing fatigue lies in the retinal-central mechanism.

Flicker is a phenomenon closely allied to contrast. Fatigue results as readily from exposure to flicker as from exposure to simultaneous contrasts. While flicker has been studied very thoroughly and the phenomenon frequently utilized in the study of visual processes, no definite explanation has been forthcoming for the vulnerability of the eye to this form of stimulation. Lancaster[3] advanced the suggestion that the basis of fatigue from flicker was the ineffectual attempt of the eye to produce a steady flux of energy upon the retina; the inability of the effector mechanism to transform a flickering stimulus into a steady flux resulted in rapid fatigue of that mechanism. While such a process is important, it can not be considered as more than simply contributory to contrast fatigue; in the light of recent work it appears that the retinal factor is the most important.

While contrast fatigue is not the only form of retinal fatigue, it is by far the most important, and the most representative of retinal behavior. The retina as a sense organ is peculiar in that adaptation plays a larger role in its function than in that of any other organ. Consequently, the retina is not suited for a quantitative interpretation of stimulation. It is commonly said that the "eye can equate but can not appraise." If contrasts were entirely removed from our field of vision, it would be almost impossible for the eye to determine whether our surroundings were bright sunlight or total

darkness. The study of contrast behavior is thus the most important method of studying visual function.

The recent studies of Granit[16] and others have emphasized the importance of the peripheral or retinal share in the analysis of visual sensation, and have helped to focus attention upon the retina as playing probably a much greater part in the analysis and interpretation of impulses coming from the sense endings than has hitherto been suspected. Sir John Parsons,[17] in 1925, pointed out the increasing evidence for complexity of retinal behavior, and stated that the duplicity theory would prove to be too great a simplification of retinal physiology. The newer work is amply bearing out his predictions.

In the light of the new knowledge of retinal function, the question of fatigue occurring in this organ becomes one of unusual interest. In the course of the present study, it appeared that of the many phases of the problem of visual fatigue awaiting experimental attack, none was as important as that of the part played by the retina in general visual fatigue. The experimental work was therefore planned as an attack upon the problem of demonstrating the occurrence of retinal fatigue, together with an attempt to estimate quantitatively its importance as compared with fatigue of other parts of the visual mechanism.

## EXPERIMENTAL

In the last ten years there have been many advances made in our knowledge of the behavior of sense organs in general. Adrian[19] has shown that all forms of peripheral sensitivity depend on functional units whose behavior is basically similar. For the sense of sight, he has shown that this basic behavior is modified so that the demonstrable changes in the eye and optic nerve are complicated by the interposition of the retina; therefore he was able to study the part played by the retina in the elaboration of the stimuli from the light sense endings. Granit[18] demonstrated that phenomena characteristic of central nervous system behavior could be shown to occur in the retina, and that therefore the retina could properly be called a true nervous center. The experimental work of Adrian and Granit on the eyes affords a basis for the experimental attack on the question of retinal fatigue.

Adrian showed in his studies on the eel's eye that the total effect of light falling on the eye was transmitted to some region whose

extent was independent of the area illuminated. In addition, he found that under certain conditions a rhythmical discharge occurred in the optic nerve as a result of action in unison of the ganglion cells in the retina. Furthermore, he showed that when four separated regions on the retina were illuminated simultaneously, the reaction time was shorter than when one was illuminated alone; this interaction between distant retinal areas was enhanced by the addition of strychnine to the prepared anatomical specimen, a drug which by its action decreases synaptic resistance. These experiments, therefore, demonstrated among other findings the presence of an interaction taking place in the retina as a fundamental part of its reaction to simple stimuli.

Granit[16] demonstrated the occurrence of interaction in the human eye by adapting Adrian's experiment to a subjective method. Using critical frequency as a criterion for the effective intensity of a stimulus, he showed that the effective intensity of a given stimulus was lower when the stimulus was presented alone than when presented simultaneously with stimuli falling on other parts of the retina. In further experiments he studied the relationship of interaction to retinal behavior, and showed that many of the properties of the visual mechanism were bound up with retinal reactions of the synaptic type.

Granit considers that, for any given amount of activity in a functioning group of ganglion cells, part of this activity results from activity beginning in receptors directly in front (distal) of the ganglion cells, and part is the result of activity coming *via* association fibers from sense endings lateral to the active cells. Any given spot of activity in the ganglion cells thus has an effective intensity which represents the sum of input over frontal and lateral channels. By the proper selection of differing types of stimulus, therefore, it is possible to distinguish between frontal and summative responsibility for changes in effective intensity. Granit demonstrated by this method that the site of adaptation lay in the sense endings rather than in the synaptic mechanism.

This method is well suited to the purpose of localizing the occurrence of retinal fatigue. By its use it should be possible not only to determine whether any fatigue occurs in the retina, but also to assign a semi-quantitative value to the various factors concerned in the causation of the fatigue.

The apparatus finally adopted was a compromise between the

ideal and one which, while suited to the various types of experiment, could be constructed with the minimum of delay. As a source of illumination, a standard projection lamp was used, mounted in a suitable lamp house. The optical system consisted of the usual condenser lenses and projection lens, so arranged that the plane of the image of the lamp filament was a few centimeters in front of the projection lens. In this plane was placed a rotating sector disk, so that when the sector disk was rotating, movements of the image of the diaphragm on the screen were negligible. The arrangement is illustrated in Fig. 1. The size and shape of the image on the

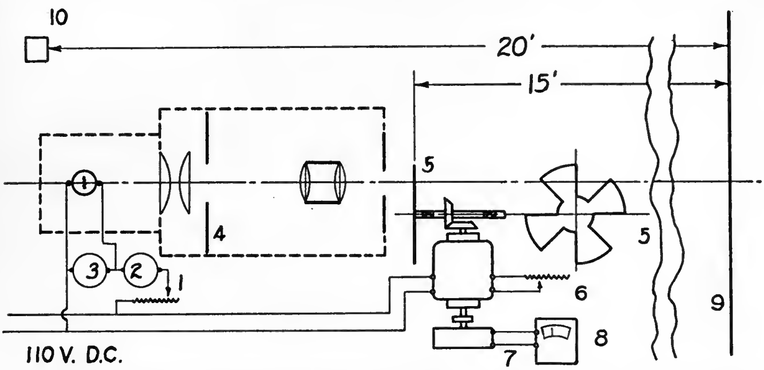


FIG. 1. Diagram illustrating the apparatus used for determining ocular fatigue: *1*, lamp control resistance; *2*, lamp circuit ammeter; *3*, lamp circuit voltmeter; *4*, projected slit; *5*, sector disk; *6*, disk motor control resistance; *7*, Western Electric tachometer; *8*, tachometer voltmeter; *9*, screen; *10*, subject.

screen were controlled by the use of different diaphragms; the intensity of illumination was varied by a resistance in the lamp circuit. This method is sufficiently accurate for the comparatively narrow range over which the variations were made. The actual intensity on the screen was measured for the different lamp amperages with a Macbeth illuminometer.

In actual practice, the subject was seated 20 feet from the screen. A preliminary period of adaptation to a very low level of illumination, lasting 20 minutes, preceded every experiment. Both eyes of the subject were always exposed to the fatiguing stimulus; the critical frequency determinations were made on the right eye. In taking the readings, an attempt was made to obtain the point at which flicker just appeared in at least 6 seconds, since this is considered the approximate length of time during which the eye can

fixate a given point without moving. If more than 6 seconds proved necessary, the reading could usually on the next attempt be made within that time, since the approximate value was then known. The speed of rotation of the sector disk was varied by a resistance in the armature circuit of the motor, and the rpm. indicated by a Weston tachometer. One sector disk was used for all the critical frequency readings.

The experiments were begun by determining the critical frequency curves for the normal eye. The curves were plotted for only two different areas of stimulation, since these two are all that are necessary. Fig. 2 shows the curves of four subjects for a stimulation area

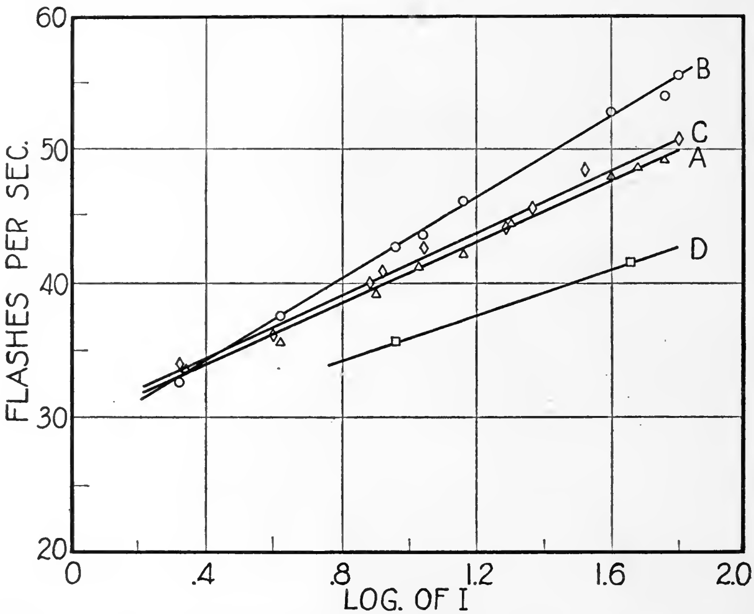


FIG. 2. Critical frequency curves for four subjects, for stimulation area of four degrees' diameter.

of 4 degrees of diameter; there is apparent a marked difference in sensitivity to flicker between different individuals, though all subjects show the usual logarithmic relationship between intensity and critical frequency.

The critical frequency for any given stimulation varies not only with the condition of the eye as a result of previous activity of the

eye, but also with the general condition of the subject. It was found that in order to obtain reproducible results, it was necessary to demand of the subjects that they always retire early the evening before, and that they do no reading before coming to the laboratory the next morning. Not more than two hours could be utilized in any one day, since readings made over a longer period of time or in the afternoon showed greater variability than those taken in the early part of the day.

The method for demonstrating and localizing the retinal fatigue

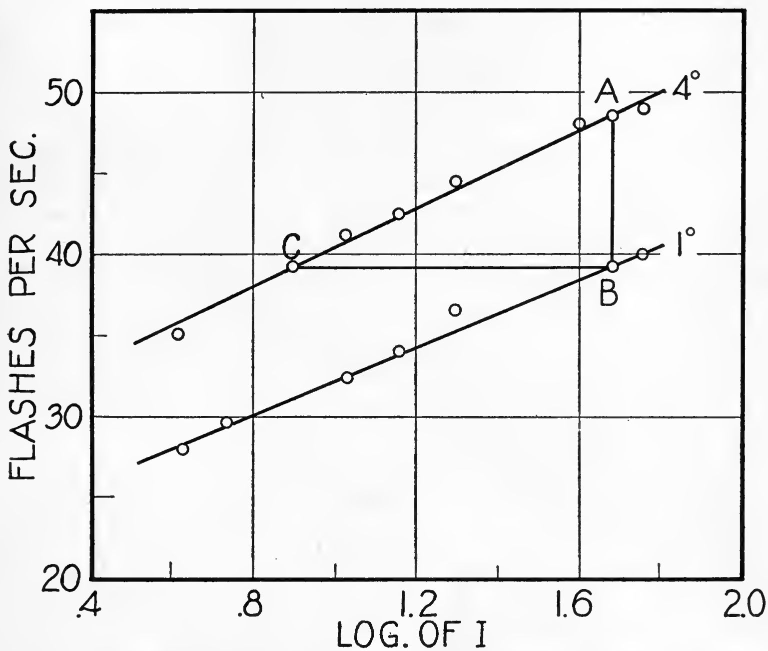


FIG. 3. Critical frequency curves derived from the curves of Fig. 2, for demonstrating the localizing of retinal fatigue.

depends on the fact that interaction plays a proportionately greater role in bringing about a given effective intensity as the area of the retina stimulated is increased. From the critical frequency curves of the subject, three points are chosen, as shown in Fig. 3. These points are so related that points *A* and *C* have the same area but different intensities, *C* and *B* the same critical frequency (effective intensity) but different areas, and *A* and *B* the same intensity but

different areas. *C* has the same critical frequency as *B* in spite of its lower intensity, because of its greater amount of interaction. *A* owes a larger percentage of its effective intensity to interaction than does *B*, because of its larger area.

In practice, the subject observed the screen for half an hour, while a slowly flickering light was projected thereon. During the half hour, five readings of the critical frequency were taken for one of the three "crucial points," *A*, *B*, or *C*; the points were presented either at random or in rotating order. Half-hour runs were also made with readings for the same point taken throughout. No reading was ever taken at twenty-five minutes in order to avoid any effect on the value at thirty minutes, although it was found that the break in the fatiguing stimulus necessary to take a critical frequency reading had a negligible effect on the subsequent readings. Since many experiments were therefore necessary to obtain the essential data, those points for which one check was obtained were included in the results; it would be better from a statistical point of view to include many readings and calculate the mean of the values obtained, but time was not available. Moreover, a more exact determination of the absolute values for the critical frequency is superfluous in view of the fact that other variables in the factors involved in the experiment can not be controlled within a variability range as small as that represented by the values for critical frequency obtained by the above method.

The analysis of the readings is shown in Fig. 4. For each of the three "crucial" points a curve is plotted showing the course of the critical frequency change with time. On the same graph is plotted a curve obtained in exactly the same manner as the first except that the "fatiguing" stimulus was not flickering. The difference between the two curves represents the fall in effective intensity resulting from the flicker characteristic of the stimulus. It therefore represents a true flicker fatigue.

Table I presents a summary of the results for the three subjects upon whom a complete set of readings was obtained. Subject *T.N.* showed the greatest susceptibility to flicker fatigue. The table shows that in one-half hour point *A* fell to an effective intensity of 10 per cent of the original value; while at the same time points *B* and *C* fell to 30 and 28 per cent, respectively, of their former levels. Thus *A*, with the largest proportion of its effective intensity due to interaction, fell the most; *C* and *B*, with relatively much

less of their effective intensity due to interaction, $C$ because of less intensity than $A$, and $B$ because of less area, have fallen much less. The other subjects show the same relationship between the three

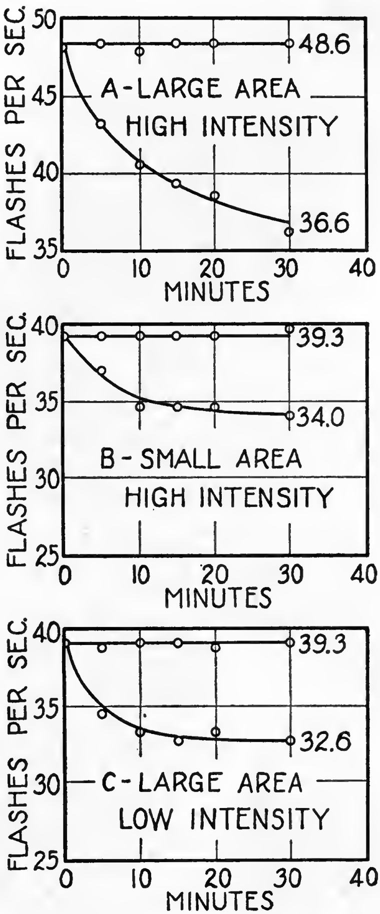


FIG. 4. Analytical curves showing the change of critical frequency with time; one curve for each of the "crucial" points of Fig. 3.

points, although not quite to the same degree. Therefore, it can be concluded that flicker fatigue takes place in the retinal-structures behind the sense endings rather than in the sense endings themselves.

TABLE I

*Summary of Experiments on Localization of Retinal Fatigue*

| Subject | Point | Area | Intensity | C.F. Start | C.F. 1/2 Hr. | E.I. Start | E.I. 1/2 Hr. | Per Cent of Original Intensity |
|---|---|---|---|---|---|---|---|---|
| *T.N.* | *A* | 4 | High | 48.6 | 36.6 | 48.0 | 4.8 | 10 |
| | *B* | 1 | High | 39.3 | 34.0 | 48.0 | 14.8 | 30 |
| | *C* | 4 | Low | 39.3 | 32.6 | 8.0 | 2.2 | 28 |
| *H.B.* | *A* | 4 | High | 44.6 | 40.0 | 19.1 | 7.6 | 39 |
| | *B* | 1 | High | 37.3 | 34.6 | 19.1 | 11.0 | 57 |
| | *C* | 4 | Low | 37.3 | 34.0 | 4.6 | 2.5 | 54 |
| *P.S.* | *A* | 4 | High | 53.0 | 41.3 | 42.0 | 7.2 | 17 |
| | *B* | 1 | High | 41.3 | 36.0 | 42.0 | 11.0 | 26 |
| | *C* | 4 | High | 41.3 | 33.3 | 7.6 | 2.3 | 30 |

The percentages given above represent definite values only for a given experiment. While they serve to differentiate quite clearly between the possible sites involved in the reaction, they are in no wise to be considered as representing the absolute value for the fatigue occurring at that site. It is not yet possible to estimate the absolute percentage of frontal and lateral contributions to the effective intensity of any excited area. Moreover the location of the stimulated area is of importance in determining the amount of interaction in the response. Therefore, the figures obtained represent only a semi-quantitative value for the local fatigue; they nevertheless demonstrate clearly the occurrence of retinal flicker fatigue and fix the responsibility for most of it upon the synapses.

Table II shows the effect of rate of flicker in the fatiguing stimulus upon the effective intensity. Not enough data were obtained to draw any very definite conclusions, but it is evident that as long as flicker is apparent fatigue occurs. When the rate of flicker is such that it is not apparent, there is no fall in critical frequency during the half-hour period.

TABLE II

*The Effect of Rate of Fatiguing Flicker upon Effective Intensity*

| Rate of stimulus | 13.3 | | 26.6 | | 53.3 | |
|---|---|---|---|---|---|---|
| | C.F. | E.I. | C.F. | E.I. | C.F. | E.I. |
| Before exposure | 40.6 | 10.0 | 40.6 | 10.0 | 40.6 | 10.0 |
| After 1/2 hour | 34.0 | 2.9 | 34.6 | 3.17 | 40.6 | 10.0 |

## DISCUSSION

The fact that fatigue from flicker depends on the perception of the flicker rather than upon the absolute rate of alternation is extremely important. These two factors are of course intimately related; the preliminary experiments show, however, that it is the subject's sensitivity to flicker which will determine whether fatigue results from exposure to a given flickering stimulus. This finding is related to the fact brought out by Grunbaum[20] that it is the ratio of time of constancy of stimulus to time of changing stimulus which has the greatest effect on the absolute value of the critical frequency rather than the rate of rotation of the sector disk. No attempt was made in these experiments to explore the relationship between flicker fatigue and sector dimensions; it is probable that the relationship will be found to be closely parallel to that of perceptibility of flicker with sector dimensions.

The curves showing the relation of effective intensity changes to exposure to non-flickering light indicate that very little effect resulted from such a stimulus. This relationship is a consequence of the conditions under which the experiment was performed. Lythgoe and Tansley[21] have recently brought out the fact that during exposure to light the critical frequency due to rod activity falls, while that due to cones rises. The type of response is determined by the illumination level of the surroundings. In these experiments, the background illumination level and the size of the screen were such that very little change in adaptation level occurred. Some of the curves do show a slight tendency toward an increase in the critical frequency during exposure to the steady stimulus, which is the type of change to be expected since the experimental conditions are such that cone responses are chiefly concerned.

Flicker is, of course, not the only environmental condition which elicits retinal fatigue. Any type of stimulus will bring about the same kind of retinal fatigue in proportion to the amount of synaptic activity involved in the retinal response. The ordinary activities of every-day life all produce a certain amount of retinal fatigue which can be detected by the method used in this investigation. When one of the subjects inadvertently read the morning newspaper before coming to the laboratory, the absolute critical frequency levels were depressed more than 10 per cent. Another subject made the mistake of spending some time in drawing, with the result that this more severe visual task left his retina in a measurably depressed state

more than three hours afterward. The depression of retinal response by normal activity is a real fatigue in the physiological sense; the fatigue must progress close to the point of exhaustion before it can intrude into consciousness and cause symptoms.

Finally, it may be profitable to consider briefly the present status of the question in connection with the motion picture. As a visual task, viewing the motion picture is essentially similar to all other visual tasks; the amount of involvement of the various functions of the visual process is modified by the factors of discontinuous stimulation, dark adaptation, and continuous accommodation for far incident to this particular form of visual work. The high degrees of contrast present and the discontinuous nature of the stimulus have both been shown to be important causes of retinal fatigue and consequent decrease in ability to see.

In Table III is presented an estimate of the relative importance of the various functions of the visual process involved in motion picture fatigue. The figures are to be considered as representing only the probable values; they are not based on any accurate quantitative

TABLE III

*Estimate of the Probable Proportions of Responsibility of the Functions of the Visual Process in the Production of Visual Fatigue by the Motion Picture*

| Function | Per Cent |
|---|---|
| Accommodation (lens) | 10 |
| Diaphragmatic function of the iris | 10 |
| Fixation | 10 |
| Pigment migration and movements of rods and cones | 0 (?) |
| Irritability to light (including adaptation) | 5 |
| Conduction and perception | |
| *a.* Retinal | 40 |
| *b.* Central | 15 |
| Control of effectors | 10 |

experiments, and are presented in the nature of a summary of the above discussion. The retina has been shown to be particularly susceptible to contrast fatigue, especially perceptible flicker. The effectors, particularly those of the uveal tract, are unable to improve the image sufficiently to compensate for the decreased efficiency of the retina; it has been shown that there probably exists a mechanism for translating the futile excessive efforts of the effectors into uncomfortable sensations and even pain. As long as the fatigue can be kept within the usual limits of other every-day visual tasks, the

existence of the fatigue will not make itself known. When this is the case, viewing the motion picture will be no more fatiguing than any other activity of the organs of sight.

ACKNOWLEDGMENT

This work was carried out under a fellowship of the Society of Motion Picture Engineers at the Institute of Applied Optics, University of Rochester. I am deeply indebted to the members of the staff for their valuable assistance and coöperation during this investigation, and especially to Mr. Gustave Fassin, who assisted materially in the design and construction of the apparatus which was employed.

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# AVOIDANCE OF EYE FATIGUE*

F. H. RICHARDSON**

***Summary***.—*The author discusses various defects in the production and projection of motion pictures, upon which the occurrence of ocular fatigue is assumed to depend. Remedies for these defects are suggested and the effect upon the patronage of a theater by the failure to apply the remedies is noted.*

Much has been written concerning the alleged straining of eyes incident to the viewing of motion pictures. Many who had little knowledge of the real facts of the matter have declared such strain to be severe; they have succumbed to the common fallacy of basing their conclusions upon inadequate data, and have failed to differentiate between the effects of viewing motion pictures that have been properly assembled and properly projected, and of viewing pictures that have been marred by avoidable and entirely unnecessary defects, which shall here be described.

A properly assembled picture, properly projected in a properly illuminated auditorium, places upon the eyes a burden that is little if any greater than that of reading ordinary book or newspaper print for an equal length of time.

However, it must be remembered that in the modern motion picture theater the viewing time is quite long. The eyes of the patrons are used continuously for the entire length of the show; and on that account every possible effort should be made to make the work that the eyes have to do as easy as possible. If all unnecessary abuses and eye shocks were eliminated, then little or no ocular fatigue would occur.

However, it must be admitted that the matter of avoiding eyestrain has been very lamentably and inexcusably neglected. It is the purpose of this paper to point out the nature of the various defects that lead to ocular fatigue and to suggest remedies for them.

In theaters, the chief cause of eye strain that lies wholly under the

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control of the projectionist and the theater manager is lack of definition in the screen image, due to the failure of the projectionist to focus the projection lens properly. This occurs particularly in theaters in which the projection distance is quite great, as it is then impossible for the projectionist to determine with the naked eye whether the sharpness of focus is optimum nor not. The projectionist should always be able to examine the screen image through a high-power double glass, held rigidly in a fixed position so as to be always available for instant use.

This is an accessory essential to good work. It is important even in theaters in which the projection distance is short; but it is rarely, if ever, found in theaters. Common sense should tell us that the projectionist should be able to examine the screen critically and frequently. He can not examine it critically with the naked eye; and he is further handicapped by the fact that in modern theaters the observation port is invariably covered with glass, usually set at an angle to the surface of the screen.

It is quite true that a few theater managers provide an opera glass of greater or less power. However, a glass that is not fixed in position is quite inadequate; usually it is deposited at the most convenient point by the man who used it last, and when wanted must be sought for. As a consequence, it is not used as often as it ought to be. Moreover, the screen usually is examined through the glass cover of the port. But in any event, a glass capable of being moved is of little value because the projectionist can not hold it steadily enough in his hands to permit him to examine critically the lines on a distant screen.

Two other causes of poor definition, which are within the control of theaters, are the presence of oil on the film, which is a matter for theater managers to take up with exchanges, as well as to make sure that oil is kept from the films while in the theater; and the presence of dirt on the projection lenses. It should be the duty of the projectionist to keep the lenses perfectly clean.

The next cause of fatigue of the eyes to be considered is travel ghost, either in sufficient amount to be obvious, or in so small an amount as to be visible only by observers near the screen; or, even then, visible only through an opera glass. Travel ghost is seen in a surprisingly large number of theaters, for the simple reason that the projectionist neglects to go down front, at least once a week, to examine the screen image critically. A point approximately twenty-

five feet from the screen is the best position from which to examine the image when using an opera glass.

Many persons, including some able projectionists, contend that when travel ghost is so faint as just to admit of detection, it can cause no harm. This is a wrong conclusion. Travel ghost in any amount tends to blur the horizontal lines of the screen image, producing upon the eyes an effect similar to that produced by a slightly blurred carbon copy of typewritten matter: even the best carbon copy is never as easy to read as the original.

Another cause of eye-strain, and a very important one, may be attributed to glare spots, the evil effects of which are, or should be, too obvious to require much discussion. The theater manager who permits a glare spot to exist within view of his audience, or any portion of the audience, is evidently inconsiderate of his own interests, and is ignorant of the seriousness of such a procedure. By way of definition: a glare spot is any spot of white light of greater brilliancy than the general illumination of the auditorium (other than the screen, of course), in the field of view of the patrons looking at the screen. A white frosted electric light bulb, white frosted light bowl, or an indirect lighting fixture located within the field of vision as one views the screen is a glare spot, and may be highly objectionable. A spot of colored light may, if of sufficient brilliancy, be a glare spot, even though, perhaps, a less serious one.

It is idle to assume that glare spots do not operate to decrease box office income. If after the show the patrons' eyes feel uncomfortable, or if the patrons are troubled with a slight headache superinduced by eye-strain, they are not as likely to visit the theater again as soon as they otherwise might. Although the patron is seldom able to place the blame where it belongs, he attributes his fatigue to the picture, not knowing or realizing that it was not the screen image but a spot of light—a glare spot—that caused his discomfort.

The remedy is obvious: eliminate glare spots. Illuminating the auditorium exactly as for a show, let the manager view the screen from various parts of the auditorium. If from any seat a white light is visible, let it be removed, or made less conspicuous. If, for any reason it is impracticable to eliminate it wholly, by extinguishing the light, let the portion that is visible to the audience be heavily tinted, preferably amber.

Too intense illumination of the screen may cause eye-strain for one portion of the audience; or, with insufficient illumination, another

portion of the audience may suffer the strain—a condition that occurs in theaters in which the viewing distance from the rear is very great. In such auditoriums, if a picture of reasonable size, which can be viewed comfortably from the front seats, be projected, intense illumination of the screen will be necessary to enable those seated at the rear to see the details of the picture with comfort, or even to distinguish them. However, if the brilliancy be sufficient for those seated at the rear, it will be too intense for those seated at the front, and may cause them to strain their eyes, particularly if other difficulties, which will now be discussed, are present.

None of us is yet able to say with confidence just what the intensity of light reflected from motion picture screens should be. That is a question that involves rather grave difficulties and many investigators have been trying to answer it for a long time. The Projection Practice Committee now is working on the problem, with hope of at least some degree of success.

The chief possible causes of eye-strain involved in viewing motion pictures that are more or less under the control of the theater manager and the projectionist have been discussed. Attention will now be directed to perhaps the worst cause of all, over which neither projectionist nor manager has any control whatsoever. That it exists is indisputable; and that it occurs to a greater or less extent in every picture produced must be admitted. The remedy is in the hands of the producers, directors, cinematographers, and film editors.

It is well known that in the human eye the quantity of light admitted to the retina is, within limits, automatically controlled; and that the adaptation of the eye to changing levels of illumination often requires an appreciable length of time. Sudden changes of intensity of illumination, occurring faster than adaptation proceeds, place a burden on the seeing process that may lead to considerable ocular fatigue. The greater the change of intensity, the longer the time required for complete adaptation.

It is evident, therefore, that so far as is possible, sudden changes of screen illumination should be avoided; but although the intensity of the projector light scource and the optical system of the projector remain unchanged, the quantity of light that reaches the screen varies constantly, often instantaneously and in extreme amounts.

Although this fact is very apparent, even to laymen, it has been almost utterly disregarded by those who make and assemble our motion picture productions; who seem to ignore the fact that

instantaneous transitions from the dim lighting of a dense scene to the full glare of an almost white screen is objectionable. Every production provides one or several examples of such a transition.

Assume a dense interior scene, in which appear two persons, one of whom hands to the other a letter to read; instantly the illumination of the screen changes from a very low intensity to that of practically the blank screen. It needs no argument to prove that such a sudden change causes a "shock" to the eyes of all those viewing the screen. In order to avoid such a state of affairs, the letter or message could be shown as in white letters on a dark gray background, or as black letters on a lighter shade of gray. The shock would thus be very materially reduced, and the message be made not only as legible, but more so, because until the eye recovers from the shock and adjusts itself to the new level of illumination, its ability to read the message without straining itself to do so will be much less than normal.

"But," the producer will protest, "it would be unnatural to show a letter on other than white paper, written with other than black ink."

Quite true; however, producers often do incorporate things not exactly natural in their productions. For example, how often have we seen the feminine "star" made up and beautifully attired, emerge from the water into which the plot had driven her, with her attire in perfect order—an effect that is admittedly unnatural. In order to conform to the nature of things, the "star" would have to emerge from the water in a damp and bedraggled condition.

Such letters and written messages constitute only one, though usually the worst cause of abuse of the eyes of theater patrons. How often do we see dense scenes followed by scenes that are much less dense. For example, an interior, or a scene in the woods, followed by a marine view shown brilliantly on the screen. The change from a brilliant scene to a dense one causes little if any harm; but a change in the opposite sense does. The difficulty could be avoided with relatively little additional trouble on the part of the directors and cinematographers. The instructions are: "At the beginning of a brilliant scene which is to follow a dense one, let the scene be underexposed and gradually brought up to normal." Certainly such a procedure would provide an interval of time during which the eye could adjust itself to the change of illumination without noticeable strain.

# RCA VICTOR HIGH FIDELITY FILM RECORDING EQUIPMENT*

SIDNEY READ, JR.**

***Summary.***—*An illustrated description is given of new sound recording equipment having an extended frequency range*[1] *and capable of making recordings and re-recordings on either 35- or 16-mm. film. Contact prints made from the 35-mm. recordings or re-recordings, when played on a reproducing equipment having a flat response characteristic, produce sound outputs that do not vary more than plus or minus two decibels over the frequency range 50 to 9000 cycles. The equipment is composed of units that are light in weight, are small and compact but rugged, consume little power and are easily installed and operated for either studio or portable use.*

*Some of the features of the equipment are* (*a*) *symmetrical variable width recording with improved ground noise reduction;* (*b*) *a new large mirror galvanometer;* (*c*) *permanent magnet ribbon microphones operated remotely from their amplifiers;* (*d*) *improved constant impedance mixer using variable bridged "T" type attenuators;* (*e*) *correction for the response of the human ear to speech reproduced at greater than normal volume;* (*f*) *new amplifying equipment providing improved quality and quieter operation;* and (*g*) *new high-quality film phonograph and recorders.*

With previous types of recording equipment, about 6000 cycles was the upper limit of uniform output when measured on a uniform-response reproducing equipment. Even at that frequency, considerable compensation was required to counterbalance the losses in the system, including processing losses. The frequency response was subject to considerable variation due to the mechanical resonance of the recording galvanometer or vibrator, the cavity resonance of the condenser microphone, and the location of the microphone in the sound field. The height of the mechanical resonance peak of the galvanometer was very difficult to maintain constant, due to the change of damping with the temperature, age, *etc.* The frequency characteristic of the condenser microphone varied considerably, depending upon the angle of incidence of the sound waves. With these variations, it was very difficult to maintain good response

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even up to 6000 cycles. The problem became more involved when re-recordings were made, especially when it was desired to combine or mix the outputs of one or more microphones with that of a film phonograph. It was necessary to compensate either for the microphones or for the film phonograph in order to obtain similar frequency characteristics; at the same time, it was necessary to maintain the correct over-all compensation. Due to these difficulties, the degree of compensation and the methods of obtaining it varied greatly from one equipment to another; and, in the case of re-recording, varied between different films. In any case, it was usually left to the discretion of the recordist.

Recent improvements in the quality of sound reproducing equipment have furnished an added incentive to improve the quality of sound recordings. It is always desirable that the quality of sound recordings be superior to that of the reproducing equipment, because sound from old recordings often is "dubbed" or re-recorded into current productions.

The film phonographs usually consisted of slightly revised standard reproducing sound-heads. This type of unit did not provide the same constancy of film speed as the recorder did, and thereby caused unnecessary distortion. Furthermore, these units abraded the film considerably.

The unusually rapid increase in popularity of 16-mm. sound-film recordings, both in industry and in the home, has provided a new field for recording, which, though new, is closely related to 35-mm. recording. It is to be expected that a large part of the 16-mm. sound film will be re-recorded from the master positive or from prints of standard 35-mm. sound recordings, as this provides a very economical means of obtaining good quality 16-mm. sound film.

It is the purpose of this paper to describe a sound recording equipment that was designed for practical operation, keeping in mind these considerations as well as others advanced by a number of studios using previous types of equipment. Some of the advantages of this equipment are as follows:

Recordings or re-recordings, or combined recordings and original recordings may be made without altering the high-frequency compensation. The output from a contact print of the recorded film, when played on high fidelity reproducing equipment, is a faithful reproduction, within plus or minus two decibels over the frequency

range 50 to 9000 cycles, of the original sound or of the output of the film from which the re-recording is made.

The operation of the equipment is greatly simplified. Considerable simplification in operation results from compensating entirely in one unit, which is common for recording and re-recording, the response of all the remaining units being essentially constant over the frequency range that it is desired to cover. This makes it possible to record or re-record without the usual difficulty of varying the compensation. The compensator panel, the unit that provides the necessary correction for losses sustained in processing, has only three degrees of compensation: namely, (1) for 35-mm. recording or re-recording; (2) for 16-mm. recording or re-recording; and (3) uniform response to provide for testing. A three-position switch, suitably designated, is provided for selecting the degree of compensation.

Compensation is provided to correct for the change in frequency response of the ear with an increase in sound intensity. As speech is nearly always reproduced at levels higher than the original, this compensation consists in attenuating both the low and the extremely high frequencies. Thus the recorded speech may be amplified to the level required in the theater without changing its quality. A switch on the microphone mixing panel provides for controlling the attenuation while speech is being recorded. This compensation is entirely independent of the compensation for processing losses previously referred to. The latter is required for recording all sounds, while both are required only when recording speech or other low level sounds.

Flexibility is improved, as regards the location of the units relative to one another. This is accomplished by making the impedance of the coupling lines between all units of such a value as to permit an appreciable distance between the units with a negligible change in frequency characteristic.

All the amplifying and control units, with the exception of the microphone and phototube amplifiers, are designed for mounting on a standard relay rack or for portable use with interconnecting cables between the different units. Also, the controls are so located as to facilitate this kind of operation. This is quite desirable because in some applications it may be convenient to locate the mixer as well as the complete amplifying and recording equipment in one room; whereas, in other applications, it may be desirable to operate the

mixer and monitoring system remotely from the other amplifying equipment; and operate this amplifying equipment, in turn, remotely from the recorder or re-recorder. A relatively small amount of power is required to operate this equipment.

A high-quality film phonograph is provided. This unit is greatly improved as to frequency characteristic and speed variation, and, in addition, abrades the film considerably less.

Fig. 1 shows a photograph of an installation at the studios of

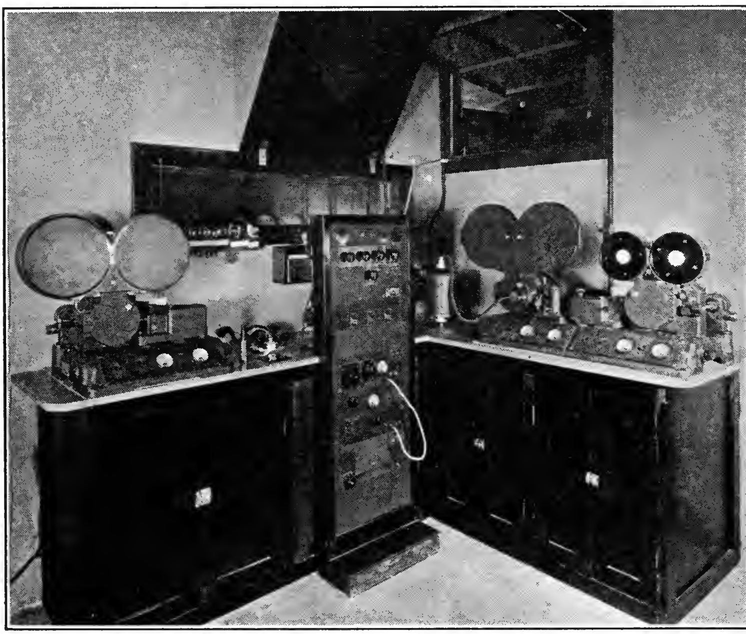

FIG. 1. High fidelity film recording system installed at the Burton Holmes Studio, Chicago, Ill.

Burton Holmes Lectures, Inc., at Chicago, Ill. From left to right are shown a 35-mm. recorder, amplifier and control rack, phototube amplifier, and a 35- to 16-mm. re-recorder (consisting of a 35-mm. film phonograph and a 16-mm. recorder mounted on the same base and mechanically connected).

Fig. 2 shows a diagram of the new recording equipment. Four microphones, type *44-A*, are connected to their respective microphone amplifiers, type *PA-82*. The impedance of each line between

the microphone and the microphone amplifier is 250 ohms. One or more of the microphones and microphone amplifiers may be replaced by phototubes and phototube amplifiers, type *PA-79*, when it is desired to re-record. The phototube is located in the film phonograph, and is connected to the phototube amplifier by a 50,000-ohm line. This line is about two and one-half feet long, and consists of a low-capacity cable well shielded against external fields. The lines between the outputs of the microphone and phototube amplifiers and the input of the microphone mixing panel have an impedance of

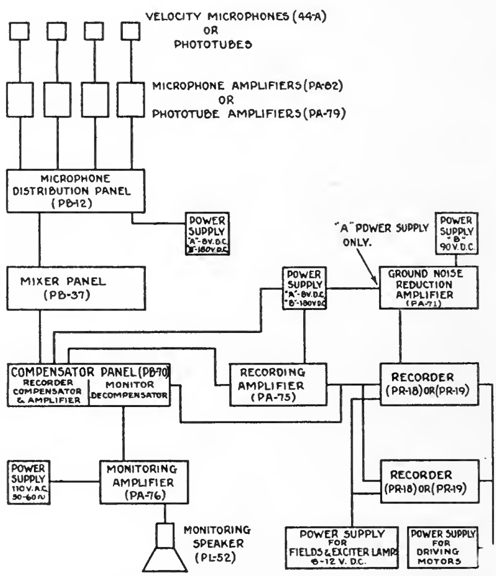


FIG. 2. Sound recording equipment; diagram of components and interconnecting cables.

250 ohms. These outputs are combined in a microphone mixer, type *PB-37*, in which it is possible to adjust independently the volume output of each microphone or phototube amplifier, as well as that of the combined output. The microphone distribution panel, type *PB-12*, serves as a junction box for connecting the outputs of the microphone and phototube amplifiers to the inputs of the microphone mixer and for furnishing the d-c. power for those units. The output of the microphone mixer is fed through a 500-ohm line into the compensator panel, type *PB-70*. This unit accentuates

the high frequencies so as to correct for the processing losses at those frequencies. The output of the compensator panel is connected to the input of the type *PA-75* recording amplifier through a 500-ohm line. This amplifier raises the audio voltage to a sufficiently high level to operate the recording galvanometers. The connection is made by means of a 500-ohm line. A small part of the energy fed to the recorder is utilized in operating the ground noise reduction amplifier, type *PA-71*. This amplifier rectifies and filters the audio voltage and furnishes a biasing current for the auxiliary or bias winding of the recording galvanometer. The input of the monitoring amplifier, type *PA-76*, is connected in parallel with the output of the recording amplifier, the connection being made through terminals on the decompensator, which is physically a part of the type *PB-70* compensator panel. The monitoring amplifier has a high-impedance input, thus requiring a negligible amount of audio power from the recording amplifier. The decompensator provides sufficient high-frequency attenuation to correct for the increase of voltage with frequency, caused by inserting a portion of the compensator into the input of the recording amplifier, as well as that resulting from the increase of galvanometer impedance with frequency.

Fig. 2 also shows the power connections to the various units. The power for the filaments in the microphone distribution panel is obtained from an 8-volt storage battery, requiring 2.5 amperes when four microphone or phototube amplifiers are used. The plate voltage is 180, supplied by medium duty "B" batteries delivering 28 milliamperes when four microphone amplifiers are used and 14 milliamperes when four phototube amplifiers are used. The same "A" supply may be used in common for this unit, the booster amplifier (single stage of amplification in the type *PB-70* compensator panel), the recording amplifier, and the ground noise reduction amplifier. However, it is usually desirable that the "B" voltage for this unit be obtained from a separate battery. The filament current for the booster amplifier of the compensator, the recording amplifier, and the ground noise reduction amplifier is obtained from a common 8-volt storage battery. These units require a total current of 6 amperes. The plate voltage for the booster amplifier of the compensator and the recording amplifier, 180 volts, is obtained from heavy duty dry "B" batteries. The total current is 60 milliamperes. The plate voltage for the ground noise reduction amplifier, 90 volts, is obtained from heavy duty dry "B" batteries, delivering

a total current of 45 milliamperes. The monitoring amplifier requires a total power of 70 watts from a 110-volt, 50- to 60-cycle source. The field of the monitoring loud speaker is excited by the monitoring amplifier. The power for the fields and exciter lamps of the recorders and film phonographs is supplied by a storage battery. An 8-volt battery is sufficient except when a film phonograph is used, in which case a 12-volt battery is required. The total current for each recorder is 7.6 amperes, while that for a film phonograph is 6.6 amperes. The power for driving the motors of the recorders and film phonographs is obtained from a 3-phase a-c. source or from a master selsyn generator. These units may be obtained for either 50- or 60-cycle as well as for selsyn operation.

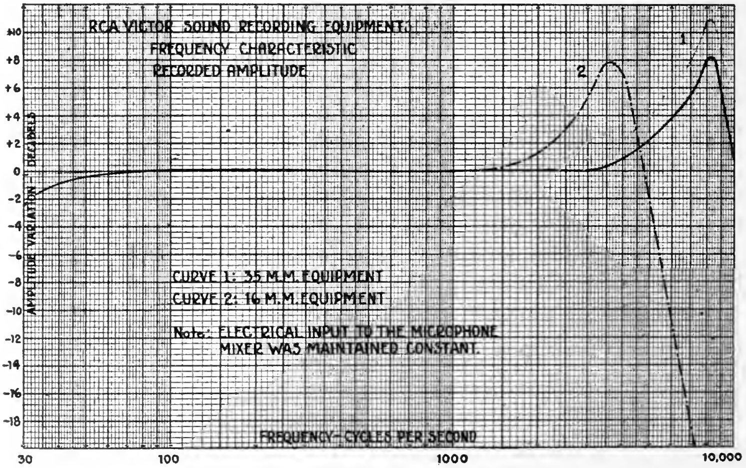


FIG. 3. Sound recording equipment; frequency characteristic of recorded amplitude.

A standard 35-mm. recording equipment, type *PM-29*, as shown in Fig. 2, weighs approximately 500 pounds, including one 35-mm. recorder, four velocity microphones, four microphone amplifiers, four 1000-ft. film magazines, and all bias batteries. Fifty pounds is the maximum weight of any unit, except the recorder, which weighs approximately 185 pounds. The total weight of the recommended plate supply batteries is approximately 125 pounds. If the amplifying equipment is mounted on a standard rack, type *9-D*, the weight of the equipment will be increased approximately 75 pounds.

Fig. 3 shows the over-all frequency characteristic, measured from the input of one of the mixers to the recorded amplitude on the film, for both 35- and 16-mm. recording or re-recording. The increase of response at the high frequencies counteracts the film loss so as to make the output from a print of the recorded film essentially constant. Of course, in order to obtain such a result, it is necessary that the sound reproducing equipment have an over-all frequency characteristic that is flat considering the width of the slit and the gas amplification of the phototube.

Fig. 4 shows the measured characteristic of a 35-mm. print made from a 35-mm. negative, which, in turn, was recorded on a production recording equipment, maintaining constant the input voltage to one of the inputs of the microphone mixer. Since the frequency characteristic of the ribbon microphone and its amplifier and that

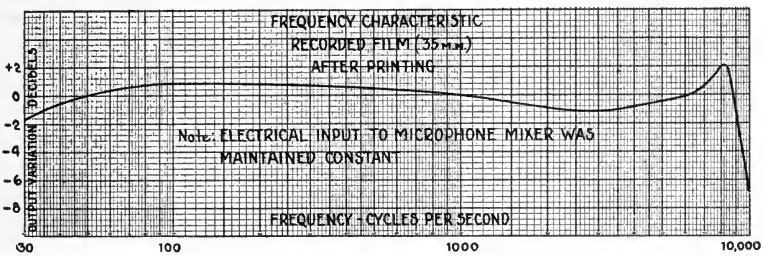


FIG. 4. Sound recording equipment; frequency characteristic of 35-mm. recorded film after printing.

of the phototube amplifier including the film phonograph slit loss are essentially flat, as will be shown later, it is easily seen from this curve how faithfully the output from prints of recorded and re-recorded films will approach the sound input to the microphone and the output from the film played in the film phonograph. This output is a faithful reproduction, within plus or minus 2 decibels, of the original sound for frequencies between 50 and 9000 cycles per second.

### RECORDERS, RE-RECORDERS, AND FILM PHONOGRAPHS

The following units are available and may be used with the same type of amplifying equipment: (1) type *PR-18*, 35-mm. recorder; (2) type *PR-19*, 16-mm. recorder; (3) type *PB-36*, 35-mm. film phonograph; (4) type *PB-38*, 35- to 16-mm. re-recorder.

Since a paper[2] giving a detailed description of these units has already been published, only the parts involved in the audio circuits will be considered.

Fig. 5 is a schematic diagram of the audio and power circuits of a 35-mm. recorder. From this diagram, it may be seen that the audio signal, on entering the recorder, passes into an impedance of 500 ohms and is stepped down to match the 2-ohm modulation coil of the galvanometer. The drop in voltage across the 25-ohm resistor, in series with the 500-ohm side of the transformer, furnishes the necessary voltage for operating the ground noise reduction amplifier. The auxiliary, or bias winding of the galvanometer,

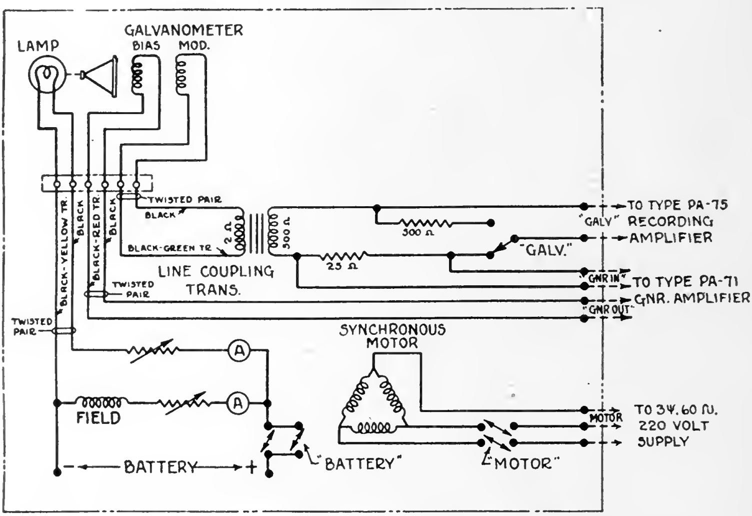


FIG. 5. Schematic diagram of model *4PR18A1* 35-mm. film recorder.

receives the proper amount of direct current to reduce the clear portion of sound track when no audio signal is applied, and to increase the clear portion sufficiently so as to prevent overshooting when modulation occurs. A more detailed description of this action will be given when describing the ground noise reduction amplifier. A switch in the audio circuit of the recorder provides for disconnecting the audio output of the recording amplifier from the modulation winding and also from the input of the ground noise reduction amplifier to allow for monitoring without the galvanometer in the circuit and for protecting the galvanometer when not in use. The galvanome-

ter furnished with this unit is of the electromagnetic type, and is more sensitive than the string or oscillograph type of unit, making it possible to use a larger mirror. The increased size of mirror reduces the stray light and allows a greater depth of focus of the slit on the film, thereby resulting in a greater response at the high frequencies. The deflection of this unit is substantially constant for all frequencies below the resonant frequency, which is 9000 cycles. The damping is such as to limit the deflection at resonance to about three decibels above the deflection at 1000 cycles.

The audio and power circuits of the 16-mm. recorder are identical to those of the 35-mm. unit, except in that a low-pass filter is inserted in the 500-ohm input circuit in order to suppress all frequencies greater than 4000 cycles. The reproduction, from 16-mm. film, of frequencies greater than that results in considerable distortion and very little useful output, because of the reduced speed of the film, thirty-six feet per minute.

The 35-mm. film phonograph is somewhat similar to the 35-mm. recorder. The recording optical system is replaced by a reproducing optical system, and the phototube is so mounted that light from the optical system passes through the sound track and thence to the light-sensitive element.

The 35- to 16-mm. re-recorder consists of a 35-mm. film phonograph and a 16-mm. recorder mounted on the same base and mechanically connected. This arrangement provides a simple means for re-recording from 35- to 16-mm. film without the usual selsyn installation.

### VELOCITY MICROPHONE, TYPE 44-A

The velocity microphone[3] provides for:

(1) A transformation of sound into electrical energy that is practically uniform at frequencies from 70 to 10,000 cycles per second.

(2) A permanent magnet type of field.

(3) A uniform directional characteristic for all frequencies.

(4) Remote operation as regards the microphone amplifier.

(5) An open circuit voltage output of 90 microvolts per dyne per sq. cm., referred to an output impedance of 250 ohms.

(6) Cushion and suspension mounting, with provision for rotation about both vertical and horizontal axes.

(7) Protection against disturbances due to wind.

Fig. 6 shows two views of the *44-A* velocity microphone, with and

without a wind screen. This wind screen can be easily attached to or removed from the microphone; it is not required for studio work, because suitable protection against wind disturbance which would

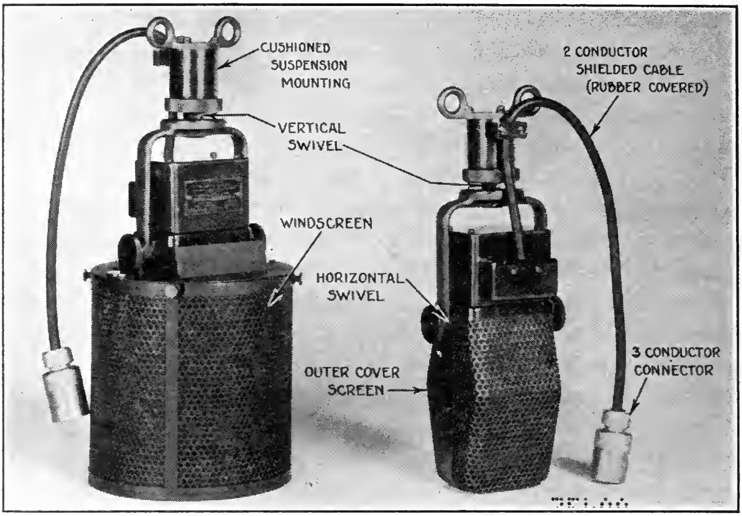


FIG. 6. The velocity microphone (*44-A*) showing suspension mounting and wind screen.

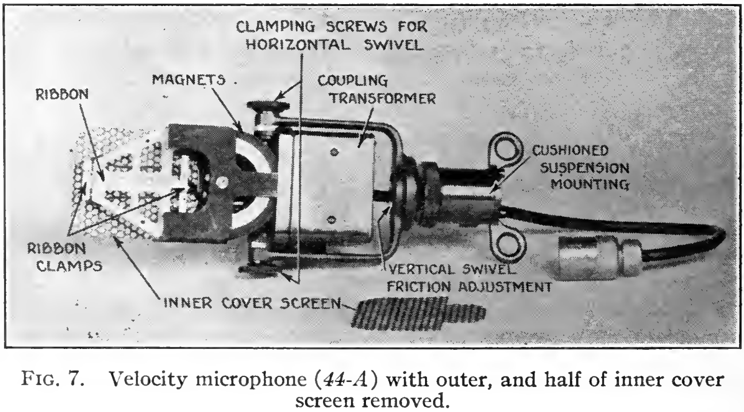


FIG. 7. Velocity microphone (*44-A*) with outer, and half of inner cover screen removed.

be encountered in this kind of work, as well as protection against damaging the ribbon, is provided by two cover screens.

Fig. 7 is a view of the microphone with the outer and one-half

the inner cover screen removed. Fundamentally, this microphone consists of a thin aluminum ribbon suspended in a magnetic field produced by permanent magnets. The sound waves cause this ribbon to vibrate in the magnetic field, thereby producing a voltage drop between the ends of the ribbon. A transformer is used for stepping up this voltage sufficiently to operate into the 250-ohm input of the microphone amplifier.

One advantage of the velocity microphone is its ability to operate uniformly, independently of changes in climatic conditions, such as atmospheric pressure, humidity, and temperature, any or all of which considerably affect other microphones.

Another important advantage of the velocity microphone is its directional property. Since the ribbon is suspended in free space, sound waves approaching the microphone in the plane of the ribbon have no effect upon it. Sound waves impinging on either side of the ribbon and perpendicularly incident to the plane of the ribbon have a maximum effect. For equal distances from the transmitter, sound waves incident at an angle of 70 or 80 degrees from the normal to the ribbon will have practically no effect; whereas, for those incident at an angle of 45 degrees from the perpendicular, the sensitivity is approximately 70 per cent of the maximum, and the quality is unchanged. The response of this microphone to sounds originating in random directions is one-third that of a non-directional microphone. For the same allowable recorded reverberation, the velocity microphone can be used at a distance 1.7 times the distance at which a non-directional microphone can be used. It is at once apparent that this characteristic is of great value in overcoming some of the difficulties encountered in reverberant sets by reducing the response to undesired reflected sounds, and in obtaining better balance and selectivity in recording. Extraneous direct or reflected sounds approaching the microphone from the side will have little or no effect. The background noises and reflected sounds are therefore reduced; an effect that increases, by comparison, the quality of the direct sounds, and reduces the necessity of using highly soundproofed booths and "blimps," provided that advantage be taken of the directional characteristic when placing the cameras. The camera, for example, may be operated outside the booth if it be placed in the "dead zone;" that is, in the plane of the ribbon of the microphone, provided that none of the camera sound is returned to the microphone from any other direction by reflecting surfaces.

This condition may generally be realized in out-of-door recording, and in the studio a considerable reduction in the amount of noise picked up from the camera may be effected.

This type of microphone responds faithfully to all sound vibrations over the range of frequencies from 70 to 10,000 cycles. Curve 1 of Fig. 8 represents the free-wave calibration of this microphone, showing that the output at 10,000 cycles is only 3.5 decibels below that at 1000 cycles. No "peaks" or "dips" occur in the characteristic of this microphone that deviate from curve 2 by more than 1 decibel, which represents approximately the degree of dependence that may be placed upon the acoustical measurements. This is a matter of prime importance in choosing a microphone, as sharp "peaks" or "dips" in the characteristic cause very objectionable

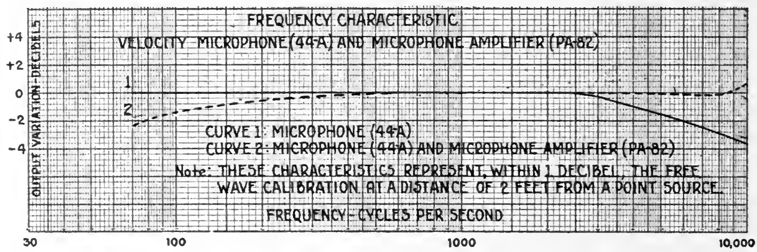


FIG. 8. Sound recording equipment; frequency characteristic of velocity microphone (*44-A*) and microphone amplifier (*PA-82*).

distortion, especially when a wide frequency range is covered. The uniformity of the response is due principally to the smallness of the size and mass of the velocity element placed in free space. Other microphones are prevented from producing as faithful a response by the size or mass of their diaphragms, or by the fact that the diaphragms are required to work against more or less closed air chambers. The faithfulness of response of this microphone imparts a naturalness of tone and a distinctness of speech not hitherto attainable with other units.

The open circuit voltage of the microphone is 90 microvolts for a sound input of 1 dyne per sq. cm. The output impedance of the unit is 250 ohms. This sensitivity is approximately $2^1/_2$ times that of the condenser microphones generally used.

**MICROPHONE AMPLIFIER, TYPE PA-82**

The microphone amplifier provides for:

(1) Sufficient amplification (50 decibels) to increase the voltage output of the velocity microphone to a suitable level for mixing.

(2) Slight accentuation of the high frequencies, so as to compensate for the reduction that occurs at those frequencies in the velocity microphone; thereby resulting in a uniform response up to 10,000 cycles.

(3) Negligible generation of noise.

Fig. 9 is a side view of the *PA-82* microphone amplifier with the cover removed and the radiotrons in position. As the photograph

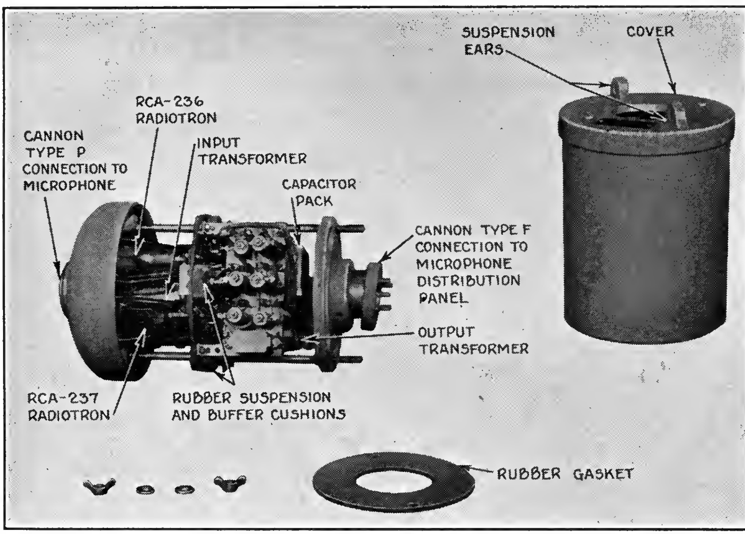


FIG. 9. Microphone amplifier (*PA-82*); cover removed.

shows, the radiotrons and amplifier assembly are mounted on cushions on two studs, which later are mounted on the base and act as a supporting structure for the case of the amplifier. The projecting portion of the studs is threaded for thumb nuts, which hold the cylindrical cover in place. Ears are provided on the cover for suspending the unit. The input connection from the microphone to the unit is made by a cannon type *P* receptacle, while the output and power supply connections are made to the microphone distribution panel by means of a cannon type *F* plug. As shown by the schematic diagram, Fig. 10, the microphone amplifier consists of an

input transformer feeding an RCA-*236* radiotron resistance-coupled to an RCA-*237* radiotron which is, in turn, coupled to a 250-ohm line by means of a step-down transformer. The bias voltage for the first stage, including the screen grid, is obtained from a "bleeder," while the second stage is self-biased. The plate and screen grid circuits are individually filtered so as to prevent disturbances from the power supply from entering the audio circuit. By using radiotrons of the heater type, such disturbances are avoided in the filament circuit. The bias resistor of the second stage is by-passed by a small capacitor, which provides sufficient high-frequency compensation to counteract the slight loss of high frequencies in the microphone.

The combined frequency characteristic of the *44-a* microphone and the microphone amplifier is shown by curve 2 of Fig. 8, which

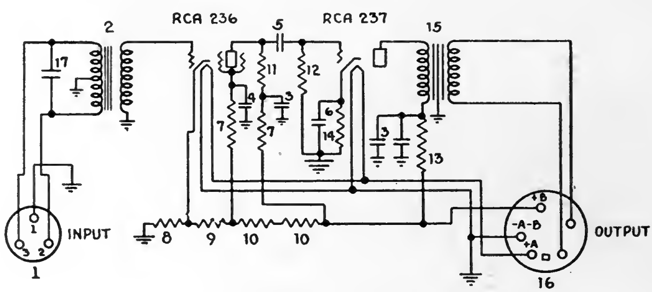


FIG. 10. Schematic diagram of microphone amplifier (*PA-82*).

does not deviate from a straight line by more than ±1 decibel, from 150 to 10,000 cycles. The response decreases slightly from 150 to 70 cycles, the response at the latter frequency being 2.4 decibels below that at 1000 cycles.

The noise generated in the amplifier, due to "shot effect" in the radiotrons and to other causes, has been reduced to a negligible value; in fact, such noise represents only about 10 per cent of the total noise that would be encountered due to the thermal agitation, at room temperature, of a high-grade 250-ohm wire-wound resistor connected across the input terminals. The plate supply required for this amplifier is 180 volts at a current of 7 milliamperes. The required filament supply is 8 volts at 0.6 amperes.

**PHOTOTUBE AMPLIFIER, TYPE PA-79**

The phototube amplifier provides for:

(1) Sufficient amplification (27 decibels) to increase the output voltage of the phototube to a suitable level for mixing with the outputs of the microphone amplifiers.

(2) Slight accentuation of the high frequencies, so as to compensate for the insufficient response of the phototube at those frequencies, as well as for the losses due to the width of the scanning slit.

Fig. 11 is a view of the *PA-79* phototube amplifier, with the housing removed and the radiotrons in place. This amplifier is of the same size as the microphone amplifier. The output and power connections are made by means of a cannon type *F* plug, and the

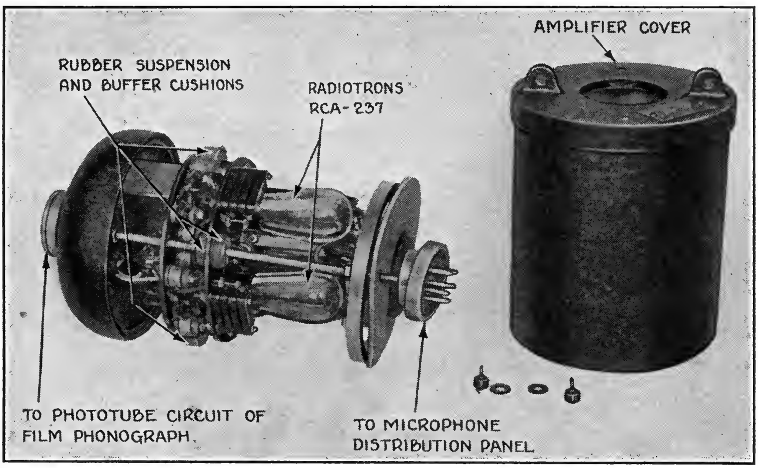


FIG. 11. Phototube amplifier (*PA-79*); cover removed.

same *A* and *B* voltages are required for this unit as for the microphone amplifier. The input is obtained from a phototube mounted in the film phonograph, as mentioned under the description of that unit. The connection from the film phonograph is made by means of a shielded cable 2.5 feet long, using cannon type *P* connectors.

Fig. 12 is a schematic diagram of the unit. The polarizing voltage of the phototube is supplied through a resistance-capacity filter and a 50,000-ohm load resistor. The impedance of the resistor is small enough to prevent appreciable high-frequency losses when

used with the connecting cable mentioned above. The load resistor is capacity-coupled to the grid of the first RCA-*237*. The output of this radiotron is, in turn, resistance-capacity-coupled to a second RCA-*237*. To the output of the latter is connected a transformer, which adjusts the impedance to match a 250-ohm line. All plate circuits are filtered by resistance-capacity networks, so as to prevent surges from the *B* supply from entering the audio circuit. By using radiotrons of the heater type, such surges in the audio circuit due to variations in the "*A*" supply are avoided.

Curve 1 of Fig. 13 is the frequency characteristic of this amplifier,

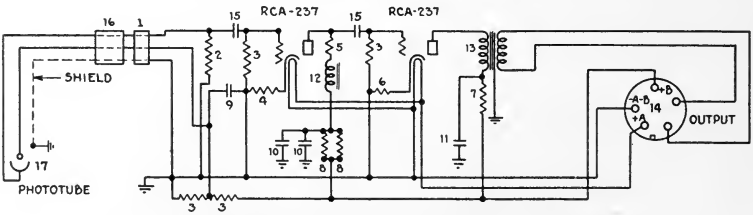


FIG. 12. Schematic diagram of phototube amplifier (*PA-79*).

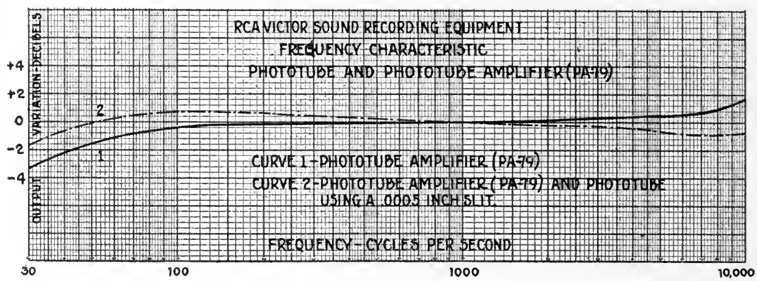


FIG. 13. Sound recording equipment; frequency characteristic of phototube and phototube amplifier (*PA-79*).

while curve 2 shows the combined characteristic of the phototube and cable and the phototube amplifier. The combined characteristic is flat within 1 decibel, from 40 to 10,000 cycles.

Since the output impedance, frequency characteristic, supply voltages, and means of making connections are identical, this unit may be used interchangeably or simultaneously with the microphone amplifier. The plate current of the phototube and amplifier is 3.5 milliamperes, at a supply voltage of 180. The filament current is 0.6 ampere obtained from an 8-volt source.

### AMPLIFIER AND CONTROL RACK

The remainder of the amplifier and control equipment is usually mounted on a standard relay rack, as shown in Fig. 14. However, any or all of these units may be operated remotely from each other. All the units are portable, as well as suitable for operation on racks.

### MICROPHONE DISTRIBUTION PANEL, PB-12

The microphone distribution panel provides for:

(1) Control of the power supply to four microphone or phototube amplifiers with suitable protection for the $A$ and $B$ sources.

(2) Separation of the audio and power circuits of the four microphone or phototube amplifiers, and connection of their audio circuits to the microphone mixing panel.

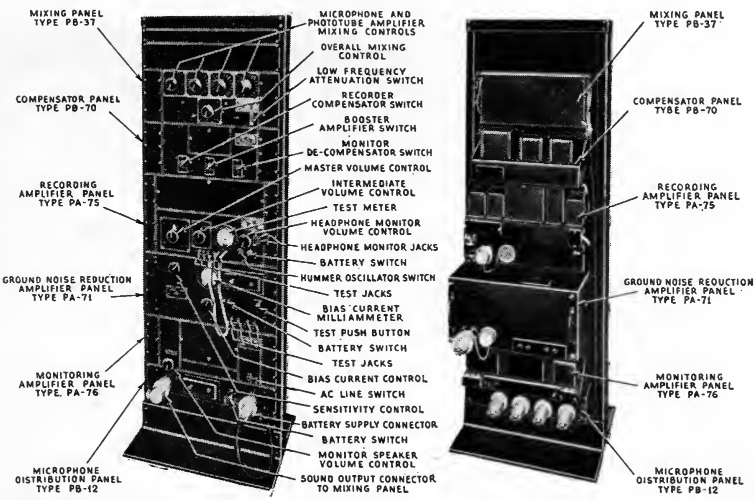


FIG. 14. ($a$) Front view of recording rack equipment; compartment covers in place; ($b$) rear view of recording rack equipment.

The microphone distribution panel is suitably constructed to be mounted either on a standard relay rack or on the wall. Fig. 15 is a front view of this unit. The front panel contains, in order from left to right, a standard cannon type $F$ eight-conductor plug, through which the microphone sound current output is fed to the microphone mixing panel and thence through the compensator panel to the main recording amplifier; a fuse box; a power switch for turning the filament and plate power on and off; and another standard cannon type $F$ male receptacle through which the filament and plate power

supply for the microphones is connected to the power plug. This latter connector may be placed on the rear of the panel if desired. The fuse box contains the signal lamp and two fuses; a 6-ampere fuse for the signal lamp and microphone filament circuits; and an 0.5-ampere fuse for the microphone plate circuits. The front cover of the box is hinged, so as to permit rapid inspection and replacement of fuses when necessary. A red bezel in the fuse box cover is located in front of the signal lamp.

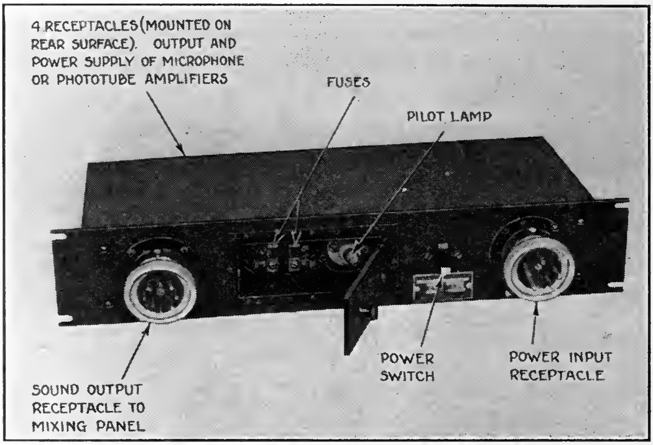


FIG. 15. Microphone distribution panel (*PB-12*).

#### MICROPHONE MIXING PANEL, PB-37

The microphone mixing panel provides for:

(1) Control of the individual audio outputs of four microphone or phototube amplifiers, having an output impedance of 250 ohms.

(2) Control of the combined output of the four amplifiers.

(3) A uniform frequency response, from 30 to 10,000 cycles.

(4) Control of the frequency characteristic of recorded speech so as to prevent a change in quality when amplified in the theater.

Referring to Fig. 16, the audio inputs to the microphone mixing panel are connected through terminals to the respective attenuators or volume controls. These attenuators are of the bridged *T* type, which make it possible to maintain the impedance constant by using only two movable contact arms instead of three, as in the conventional *T* type of attenuator. The reduction in the number

of moving contacts contributes largely to the smoothness, silence, and the dependability of these controls. The series resistors, *R-6*, *R-7*, *R-8*, and *R-9*, in combination with the attenuator pads and the coupling transformer, *T-1*, provide a constant impedance for the outputs of the four microphone or phototube amplifiers, as well as a constant impedance at the output terminals of the microphone mixer. Of course, if one or more microphones are disconnected from the input terminals of the mixer, it is necessary to turn the attenuator controls to zero in order to preserve the constant impedance relation. The

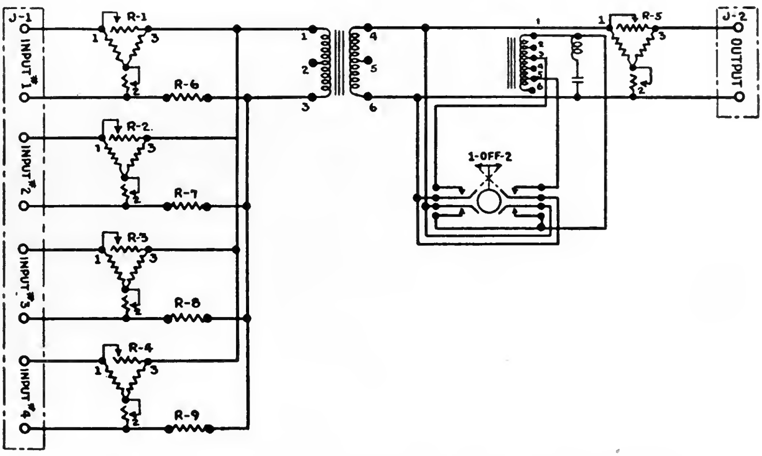


FIG. 16. Schematic diagram of microphone mixing panel (*PB-37*).

loss of power in the microphone mixer is only 8.5 decibels when all the controls are in the position of maximum volume.

In the output circuit of the coupling transformer are connected a volume control for controlling the over-all volume output of the mixing panel, and a compensator and three-position key-switch for introducing attenuation at both the low and the extremely high frequencies. Attenuation is required at such frequencies when speech is recorded at a normal level and then reproduced at a higher level, as is usually the case in sound motion picture theaters. This compensation corrects for the change in frequency response of the human ear with an increase in sound intensity; thereby making it possible to amplify the recorded speech to the desired level without changing its quality. It may be of interest to note that the com-

pensated volume control as used on radio receivers and phonographs has the opposite effect, at low frequencies, from that of the speech compensator; however, no attenuation of the extremely high frequencies is attempted, since the upper response frequency of most radio receivers is 4000 or 5000 cycles, in which range the characteristic of the ear does not change greatly. The recording speech compensator provides for good quality of reproduction of speech at intensities greater than the original, as contrasted to the compensated volume control of radio receivers, which provides for reproducing music at abnormally low levels without changing its quality.

Fig. 17 shows the frequency characteristics of the microphone mixer for the three positions of the speech compensator switch. With this switch in the center position, no compensation is provided,

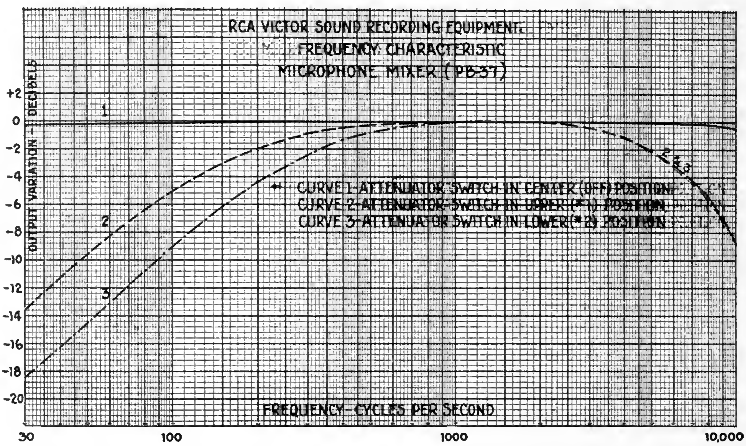


FIG. 17. Frequency characteristic of microphone mixer (*PB-37*).

and the response is uniform within plus or minus 0.3 decibel, at all frequencies from 30 to 10,000 cycles. An attenuation of 5 decibels at 100 and 8000 cycles is produced when the switch is in the upper position, and of 9 decibels at 100 cycles and 5 decibels at 8000 cycles in the lower position. The characteristic obtained with the switch in the lower position is suitable for recording conversational speech or dialog, while that with the switch in the upper position is adapted for recording lectures. The amplification system was so adjusted that the reproduced output was equal in volume to that of the original speech. The amplification of the system was then

increased, and its frequency characteristic so adjusted as to prevent an apparent change in quality due to amplifying the original speech. The results were then checked by actually recording and reproducing speech in the theater. Under actual operation it was found that one characteristic at the high-frequency end of the spectrum was satisfactory, whereas two different characteristics were required at the low-frequency end. The average of these characteristics agrees quite closely with the calculated value, as deter-

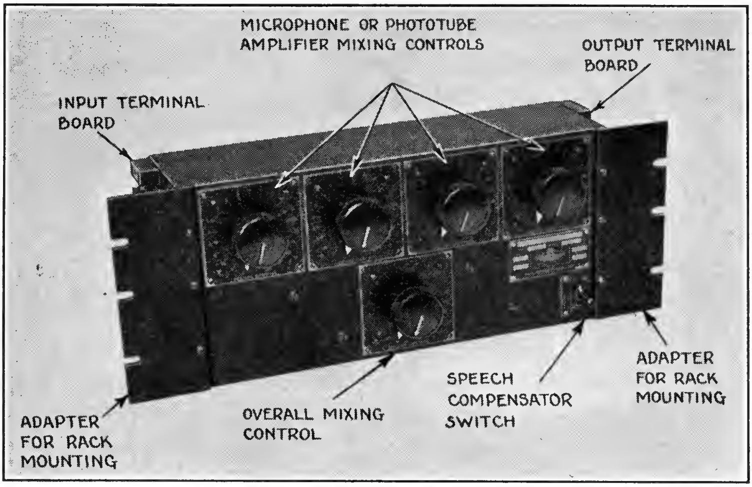


FIG. 18. Microphone mixing panel (*PB-37*).

mined from Dr. Fletcher's[4] contours of equal loudness for pure tones, assuming a change in loudness from 50 to 70 decibels.

Fig. 18 is a front view of the unit. The mechanical construction is of very high quality throughout, and it is assembled in such a manner as to facilitate the installation and operation of the unit. The front panel, which bears the four mixing controls, the over-all volume control, and the speech compensator switch, is of such a size and its mounting holes are so spaced that it may be easily mounted upon a standard relay rack. The input terminal board is located at the left of the unit, and the output terminal board is at the right. The entire unit is completely shielded electrically by a sheet metal enclosure. The rack adapters may be removed for making the unit portable.

**COMPENSATOR PANEL, TYPE PB-70**

The compensator panel provides for:

(1) Accentuation of the recorded amplitude of the high frequencies so as to compensate for the recording and processing losses of either 35- or 16-mm. film.

(2) Sufficient amplification to overcome the inherent loss due to the compensator circuit.

(3) Sufficient compensation of the monitoring amplifier so that the monitoring loud speaker faithfully reproduces the original sound.

The compensator panel really consists of three individual units, each having its own control switch; namely, (1) a compensator, for counterbalancing the recording and film processing losses at the high frequencies; (2) a booster amplifier, for counterbalancing the loss due to the compensator; and (3) a decompensator, for counteracting

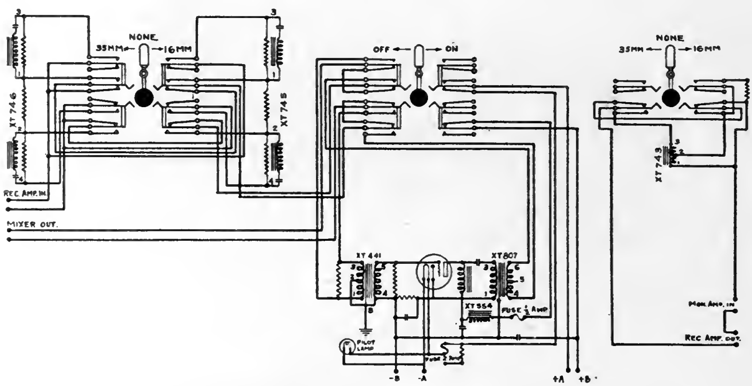


FIG. 19. Schematic diagram of compensator panel (*PB-70*).

the effect of the compensator, as regards the input to the monitoring amplifier, as well as the loss at high frequencies in the monitoring loud speaker. The first two units are inserted in the line between the microphone mixer and the input of the recording amplifier, while the last unit is inserted in the input line to the monitoring amplifier. The first two units are suitably shielded from the decompensator to prevent coupling between the input and output circuits of the recording amplifier. Referring to the schematic diagram of Fig. 19, the recording compensator is shown on the left, the booster amplifier in the center, and the decompensator on the right.

The compensator will be considered first. The output of the

microphone mixer and the input of the recording amplifier are connected to the terminals so designated. The switch at the left provides for inserting either the 35-mm. compensator unit, *XT-745*, or the 16-mm. unit, *XT-746*, or for direct connection. The compensator units consist of two similar series resonance circuits, each shunted by a resistor. One of the resonant circuits is inserted in each side of the line, so as to provide electrostatic balance, and a resistor is shunted across the input circuit. The action of the compensator units is such as to accentuate the recorded amplitude of the high frequencies, up to 9000 cycles and 4000 cycles, on 35- and 16-mm. film, respectively, so that the compensator has an effect equal and opposite to that of the film losses. This results in true and faithful reproduction throughout the frequency ranges of 50 to 9000 cycles and 50 to 4000 cycles, from prints of 35- and 16-mm. recordings, respectively.

The booster amplifier will be considered next. The switch, shown in the center of Fig. 19, provides for inserting the booster amplifier in the audio circuit, ahead of the compensator units when they are in the circuit, and for controlling the *A* and *B* voltages of the radiotron. When this switch is turned *off*, the amplifier battery is *off*, and the amplifier stage is disconnected from the recording channel. When this switch is set at its center position, the amplifier battery power is turned *on*, but the amplifier circuits are still disconnected from the recording channel. When the switch is turned *on*, the amplifier is connected to the recording channel, and provides sufficient amplification to overcome the losses of the compensator unit. The booster amplifier is a single-stage unit, employing an RCA-*237* radiotron and having input and output impedances of 500 ohms. One half of the loading of the input transformer is across the primary and the other half across the secondary, so as to obtain an improved frequency characteristic. A step-down transformer provides for coupling the plate of the radiotron to the 500-ohm input of the recording amplifier. A reactor and coupling capacitor are used to prevent the d-c. plate current from saturating the output transformer. This amplifier has a gain of 15 decibels, and a frequency response that is uniform within $\pm 1/2$ decibel for all frequencies between 30 and 10,000 cycles. Such a curve is shown in Fig. 20. The plate circuit of the radiotron is adequately filtered, and the heater type of filament provides sufficient isolation of the cathode circuit from the *A* supply. The plate circuit requires a voltage of 180 volts and a

current of 2.5 milliamperes, and the heater and indicating lamp a voltage of 6–8 volts and a current of 0.5 ampere.

The decompensator will now be considered. Due to the compensation (as described above) of the audio-frequency currents from the microphone mixer to the recording galvanometer, and to the increase of the impedance of the recording galvanometer with frequency, the sound from the monitoring loud speaker would be objectionably high pitched if the monitoring amplifier were bridged directly across the input of the recorder. The switch shown at the right side of Fig. 19 provides for inserting a reactor in series with the monitoring amplifier when recording 16-mm. film, and for inserting part of the latter reactor (in shunt with a resistance), in series with the input circuit of this amplifier when recording 35-mm. film. This decompensation causes the sound output of the monitor-

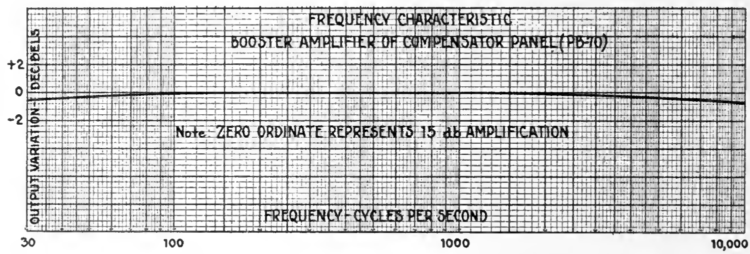


FIG. 20. Sound recording equipment; frequency characteristic of booster amplifier of compensator panel (*PB-70*).

ing amplifier to be a faithful reproduction of the original sound up to frequencies of 4000 and 7000 cycles for 16- and 35-mm. operation, respectively. The output for a frequency of 9000 cycles, in the latter case, is approximately 5 decibels below that for 1000 cycles.

Fig. 21 shows a front view of the compensator panel, type *PB-70*.

## RECORDING AMPLIFIER, PA-75

The recording amplifier provides for:

(1) Amplification of 80 db., with 66-db. control in 2-db. steps.
(2) Sufficient undistorted power output for the operation of two recorders.
(3) A frequency response of $\pm 1/2$ db. from 30 to 10,000 cycles.
(4) Self- or battery-biased operation.
(5) Head-phone monitoring with volume control.

(6) Self-contained 1000-cycle microphone hummer for checking and adjusting the recording galvanometer and ground noise reduction system.
(7) Metering of filament, plate, and bias circuits.

The recording amplifier is a compact, ruggedly constructed unit for amplifying the output signal from the microphone mixing panel (type *PB-37*) sufficiently, and for furnishing ample power to operate one or two 35-mm. or 16-mm. recorders. Its circuits incorporate four stages of amplification, three voltage and one push-pull power, utilizing a combination of resistance and transforming coupling.

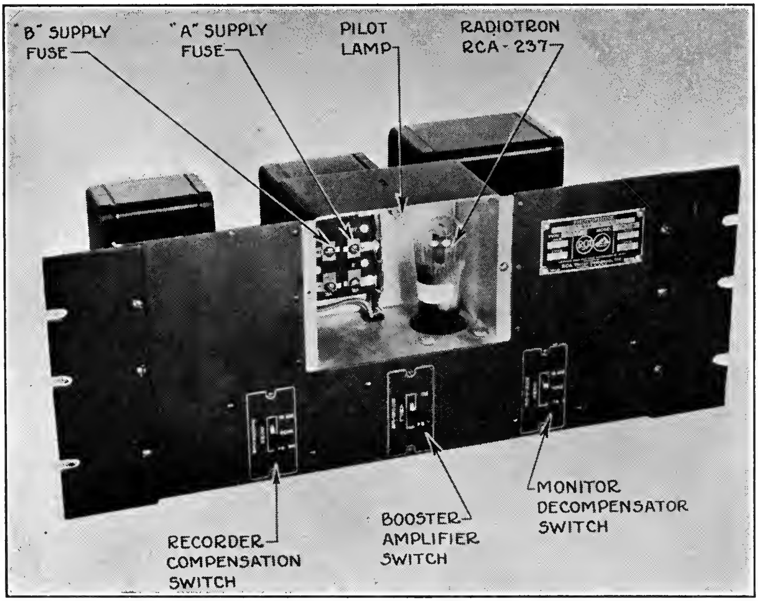


FIG. 21. Compensator panel (*PB-70*).

The following radiotrons are used: two RCA-*237's*, one RCA-*236*, and two *UX-171-A's*. The amplifier is very carefully shielded, and its power circuits are adequately filtered to prevent extraneous noises from entering the audio circuits. The microphonic disturbances have been greatly reduced by using ruggedly constructed and adequately cushioned radiotrons. High-grade wire-wound resistors are used in all circuits so as to insure against noises due to defective resistors. Noises generated electrically in the amplifier

circuits due to "shot" effect, or other causes, have been reduced to negligible magnitudes. This amplifier has a gain of 80 db., and a maximum undistorted power output of 800 milliwatts. The input impedance is 500 ohms; the output impedances are 500, 250, and 167 ohms, providing for the parallel operation of one, two, or three 500-ohm loads. As may be seen in Fig. 22, the frequency response of this unit does not vary more than $\pm 1/2$ db. over the frequency range 30 to 10,000 cycles. Even at 16,000-cycles, the response is approximately 1 db. below the 1000-cycle response.

Two volume controls are provided: the master control across the secondary of the input transformer having nineteen steps of 2 db. each, and an *off* position; the intermediate, or interstage, volume control having three steps of 14 db. each. The combined operation

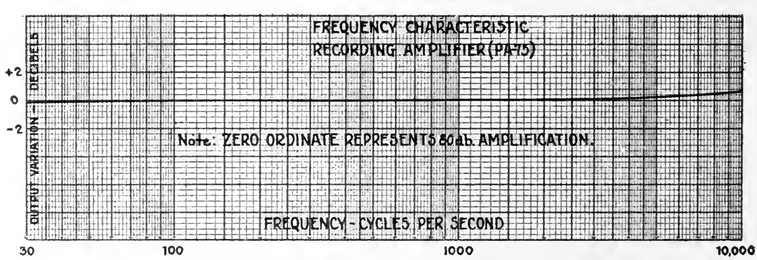


FIG. 22. Sound recording equipment; frequency characteristic of recording amplifier (*PA-75*).

of the two controls furnishes a range of volume of 66 db., in steps of 2 db. Also, a volume control is provided for adjusting the audio level for applications in which headphones are used for monitoring.

For adjusting the ground noise reduction amplifier, which will be described later, a microphone hummer (oscillator) is mounted in the recording amplifier. This hummer is used as a source of constant frequency (approximately 1000 cycles), and is connected ahead of the master volume control by means of a rotary switch. Both volume controls may then be used in the usual way, for adjusting the amount of 1000-cycle power furnished by the amplifier to the recording galvanometer. The switch may be closed by inserting a coin or a screw driver in the slotted switch-shaft and rotating this shaft; this prevents the possibility of accidentally turning on the oscillator switch while recording.

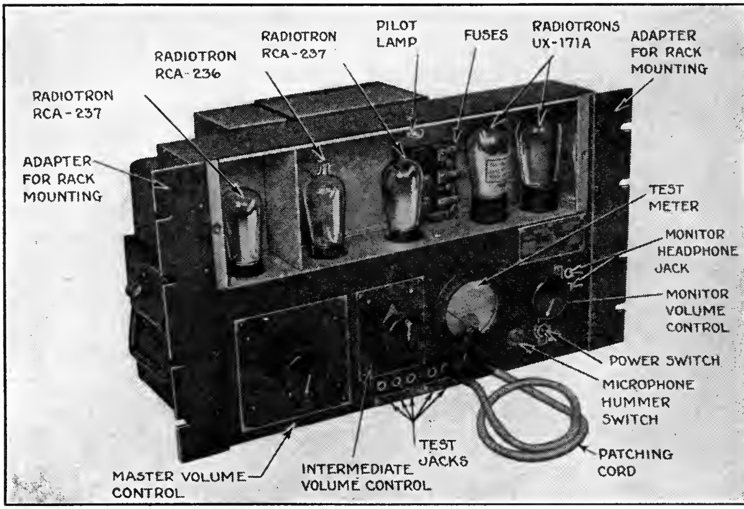


FIG. 23. Front view of recording amplifier (*PA-75*), showing interior of radiotron compartment.

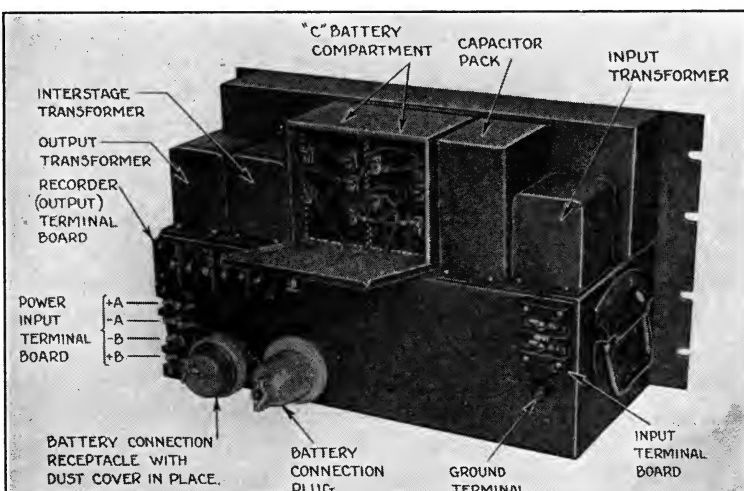


FIG. 24. Rear view of recording amplifier (*PA-75*).

The plate circuit requires a voltage of 180–225, and a current of 55 milliamperes, obtained from heavy-duty dry batteries. The filament current is 1.5 amperes, to be obtained from a 6- to 8-volt storage battery. No *C* battery is required for the first three stages of amplification, and the push-pull output stage may or may not require such a battery, depending upon the power supplies available. If a *C* battery is used, either side of the filament battery may be grounded, the required plate voltage being in that case 180 volts. If the tubes are self-biased, a 225-volt plate supply is necessary. Fuses of the link type are used in the power circuits.

Figs. 23 and 24 are front and rear views of the amplifier. The

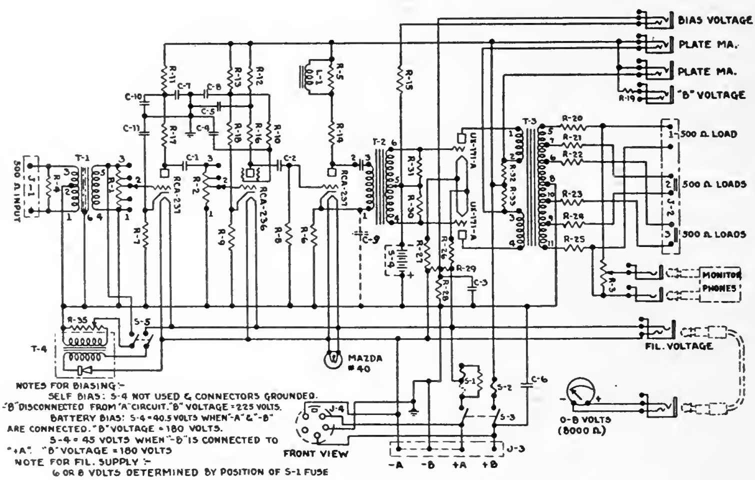


FIG. 25. Schematic diagram of recording amplifier (*PA-75*).

short length of relay panel mounted on each end of the front provides for mounting the unit on a standard relay panel. When the amplifier is to be used portably, these short lengths of panel may be easily removed. All connections are made beneath the fabricated base. Connecting wires to the panel are sufficiently long to allow the panel to be hinged about the base of the tube compartment, thus providing easy access to the wiring and the internal parts.

Referring to Fig. 25, *R-1* and *R-2* represent the master and intermediate volume controls, respectively. The screen grid radiotron, RCA-*236*, is used in the second stage rather than in the first stage so as to prevent a change in frequency characteristic when the posi-

tion of the contact arm of the intermediate volume control, *R-2*, is changed. By placing this volume control in the plate circuit of the RCA-*237*, such a change in the frequency characteristic is reduced, because the impedance of this circuit is much lower than that of the RCA-*236*. With the present arrangement, the frequency characteristic at any position of the volume control deviates from that shown in Fig. 22 by less than $^1/_2$ db.

Resistors, *R-15, R-19, R-32,* and *R-33,* in conjunction with a high-resistance voltmeter and open circuit jacks, provide for measuring the voltages and currents. This meter is used also to measure the currents and voltages of the ground noise reduction amplifier. The meter shunt resistors, *R-32* and *R-33,* are connected in the low side of the output transformer primary so as to prevent feed-back or high-frequency losses due to the metering circuit. Either a 6- or 8-volt *A* supply may be used by connecting fuse *S-1* between the appropriate pairs of terminals. When the fuse is connected between the upper terminals, an 8-volt supply is required; when between the common and the lower terminals a 6-volt source is required.

The output stage obtains its bias voltage from the *C* battery, *S-4*, or the voltage drop in the resistor, *R-28*, caused by the d-c. plate current flowing in it. When a battery is to supply the bias, the minus *B* terminal is connected to either the minus *A* or plus *A* terminal, short-circuiting the bias resistor, *R-28*. When self-biased, this connection is removed, the battery *S-4* is disconnected, and the circuit is closed; a binding post is provided in the *C* battery box for connecting these leads together. It is necessary to increase the *B* voltage from 180 volts to 225 volts for self-biasing; the voltage amplifier stages operate satisfactorily with either value of voltage.

Resistors *R-20* to *R-25*, inclusive, are inserted into the output circuits so that the output radiotrons may be matched to the correct impedance for delivering maximum undistorted power while maintaining the output impedance of the amplifier equal to the load impedance. Half the resistance is inserted into each side of the line, so as to maintain a balanced output. The impedance of the recorder at 1500 cycles is approximately 500 ohms, which is equal to that of the amplifier output circuit, while at low frequencies the recorder impedance decreases to about 70 per cent of this value. If the series resistors were not used and the ratio of the output transformer were changed so as to match the recorder, as stated above, the output radiotrons would be working into an impedance less

than their plate impedance; whereas the load impedance should be about three times the plate impedance of these radiotrons for maximum power output with a minimum of distortion. If the load impedance were matched to the plate impedance, the same amount of distortion would occur when delivering an output power of 500 milliwatts as now occurs when delivering 800 milliwatts. Of course, making the impedances equal would allow a greater output of power when distortion is not considered. Also, the present method of matching results in a slight loss of amplification compared with what would be obtained with equal impedance matching.

The oscillator (microphone hummer), *T-4,* obtains its exciting current from the filament battery. Part of its 1000-cycle output is applied across the input of the master volume control by means of the potentiometer, *R-35.* Switch *S-5* controls the audio and power circuits.

### MONITORING AMPLIFIER, PA-76

The monitoring amplifier provides for:

(1) Complete a-c. operation.
(2) An amplification of 27 db. with a 40-db. control of volume.
(3) High impedance (bridging) input, so as to require negligible power from a 500-ohm line.
(4) Sufficient undistorted power output (4 watts) for operating two monitoring loud speakers.
(5) Field exciting current for one loud speaker.
(6) A frequency response of $\pm 1/2$ db. from 30 to 10,000 cycles.

A loud speaker placed in the recordist's booth enables him to observe aurally the effect of manipulating the mixing controls, so that the recording, when reproduced in the theater, will reflect accurately the impressions, moods, and ideas that the director and recordist desire to create. To serve properly such a purpose, the monitoring loud speaker and amplifier must be of the highest quality.

The monitoring amplifier shown in Figs. 26 and 27 is a small, compactly built, semi-portable unit, completely operable on any 110–120-volt, single phase, 50–60-cycle supply. About 70 watts of power are required. This unit is designed to be connected to the main recording amplifier output circuit through the decompensator of the compensating panel, type *PB-70,* without requiring appreciable audio power input, and to furnish sufficient undistorted power for operating one or two monitoring loud speakers. Although the

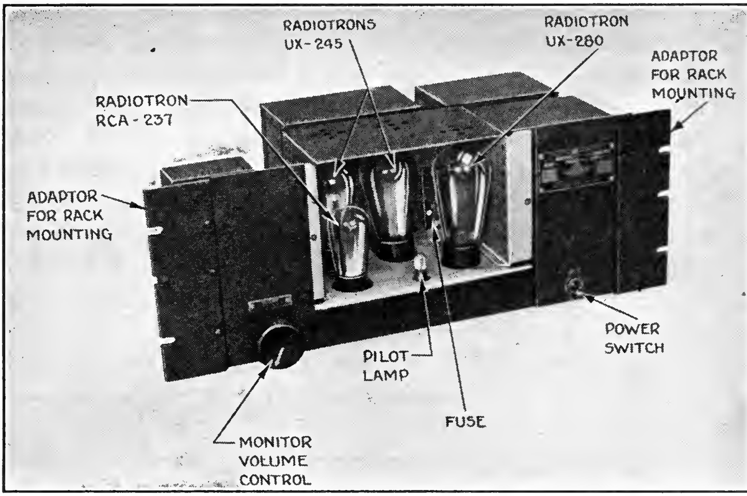


FIG. 26. Front view of monitoring amplifier (*PA-76*), showing interior of radiotron compartment.

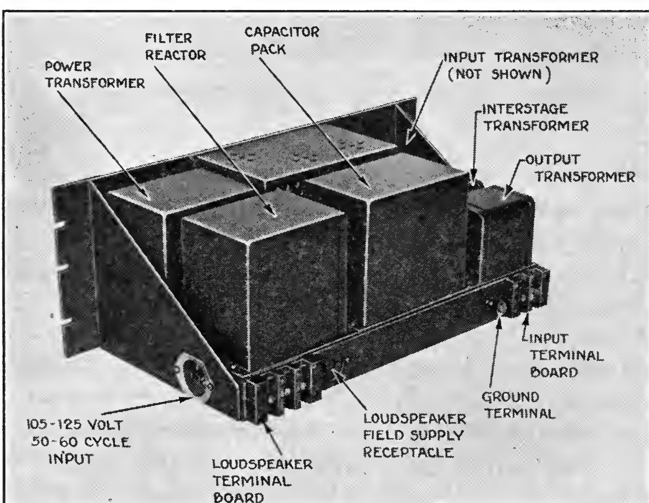


FIG. 27. Rear view of monitoring amplifier (*PA-76*).

monitoring amplifier is operated on alternating current, the output hum in the monitoring loud speaker is below the audible level at any setting of the volume control. Fig. 28 shows that the response of this amplifier does not vary more than $\pm 1/2$ db. over the frequency range 30 to 10,000 cycles. An output power of 4 watts may be obtained without exceeding 5 per cent distortion.

The unit consists of a steel base on which are mounted the transformers, reactors, capacitors, *etc.* On the front edge of the amplifier base are mounted the volume control and the power switch. On the back edge of the base are mounted the input terminal strip, output terminal strip, and a two-conductor receptacle for the monitor loud speaker field. A wall-type two-conductor plug for the 110-volt power supply is mounted on the side of the base. On top of this base and at the front edge is mounted a steel compartment containing

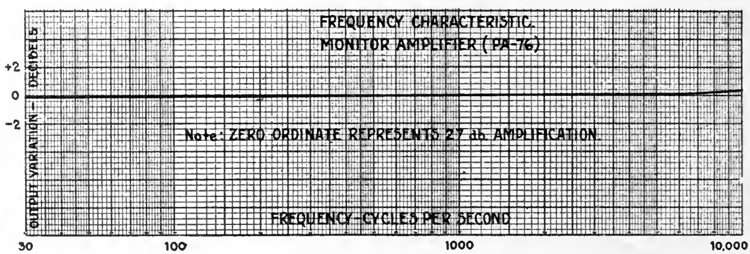


FIG. 28. Sound recording equipment; frequency characteristic of monitor amplifier (*PA-76*).

the tubes, fuse, and indicating lamp. A front cover is provided for this compartment, removable by loosening two thumb screws, thus providing easy access to the last-mentioned parts.

Referring to Fig. 29, the input transformer, *T-1*, loaded with the 100,000-ohm volume control, *R-1*, has an input impedance of 20,000 ohms, making possible the bridging of this amplifier across a 500-ohm line without requiring appreciable power from that line. The first audio stage utilizes an RCA-*237* radiotron, resistance-capacitance coupled to a push-pull transformer that furnishes audio voltage to the grids of the *UX-245* radiotrons. The first stage obtains its bias voltage from the bleeder resistors, *R-3* and *R-6*. Bias for the *UX-245* radiotrons is obtained from part of the voltage drop in the speaker field, which is connected between the ground and the negative side of the rectified plate voltage supply. The total plate current

plus the bleeder current is equal to 100 milliamperes, which is the amount of current required for the 100-volt speaker field. By this arrangement it is possible to obtain the plate and the bias voltages, 275 and minus 54, respectively, for the *UX-245* radiotrons, as well as the exciting current for the loud speaker field from a single *UX-280* rectifier. The output transformer has three secondary terminals from which one 15-ohm speaker, or two in series, may receive audio power when the appropriate pair of terminals is used. Either a 110- or 120-volt source of power may be used by connecting the fuse, *S-2,* between the appropriate pair of terminals. The fuse serves as a tap-changing switch for the power transformer, *T-4,* which furnishes the correct alternating filament voltages for the RCA-*237,* *UX-245,* and *UX-280* radiotrons, as well as the plate and field

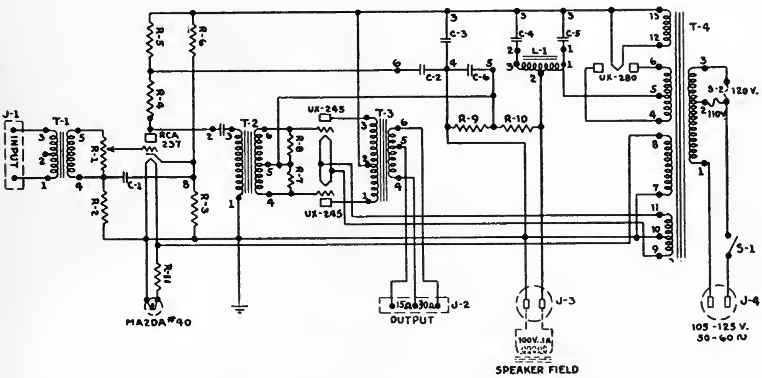


FIG. 29. Schematic diagram of monitoring amplifier (*PA-76*).

supply, which is rectified by the *UX-280* radiotron. Reactor *L-1,* in combination with capacitors *C-4* and *C-5,* forms a tuned filter for the plate and grid circuits and for the loud speaker field. The speaker field and the capacitor, *C-3,* provide additional filtering for the plate and grid circuits of the first stage and for the plate circuit of the power stage. A resistance-capacitance filter, composed of resistors *R-9* and *R-10* and capacitor *C-6,* provides additional filtering of the grid circuit of the power stage. Further filtering is provided for the grid and plate circuits of the first stage by the resistance-capacitance filters, *R2-R3-C1* and *R5-C2,* respectively. By placing the filtering reactor and the speaker field in the negative side of the high-voltage circuit, the maximum voltage to ground from the

speaker field circuit is 100 volts, while the maximum voltage to ground from any part of the amplifier is 275 volts. These voltages to ground are considerably less than they would be if the filtering were accomplished in the positive side of the rectifier circuit. In that case, the voltage from one side of the speaker field to ground would have been 375 volts, and special precautions would have had to be taken in insulating the wiring to the speaker field.

### GROUND NOISE REDUCTION AMPLIFIER, TYPE PA-71

The ground noise reduction amplifier provides for:

(1) Sufficient biasing current through the auxiliary winding of the recording galvanometer to reduce the clear portion of the sound print to a track 2 mils (0.002 of an inch) wide when no sounds are being recorded, thus greatly reducing the reproduced surface noises.

(2) Increasing the width of the clear portion of the sound track to provide for recording the signal currents impressed on the modulation winding of the recording galvanometer.

(3) Adequate filtering and timing to prevent the recording of reproducible vibrations due to the biasing action.

Previously, two methods of reducing ground noise have been employed in commercial variable width methods of recording. Both systems were used in conjunction with a variable width sound track that was a single-edged black silhouette of the sound wave. In the first system, the center of the recorded wave was shifted toward one edge of the sound track, resulting in a narrow transparent line at this edge of the printed sound track when no signal was applied. In the second system,[5] the center line of the recorded wave was kept in the center of the sound track, and a mechanical shutter was used for reducing the amount of transparent area of the printed sound track, resulting in a narrow transparent line at the center of the track when no signal was applied. When the signal was applied, the shutter was deflected sufficiently to clear the peaks of the light vibrations.

The new, or third, method of reducing ground noise is applicable to a symmetrical or double-edged variable width sound track. Fig. 30 (*a*) is a positive print of a 35-mm. negative speech record, extending over one complete cycle of operation of the ground noise reducing system. As shown in the illustration, the sound track consists of two similar waves, or oscillograms, of the voice modulation, which are symmetrical about the center of the sound track. The area of the sound track between these waves is transparent, while the remainder

of the track is opaque. The distance between the center lines of the waves increases and decreases as the amplitudes of the waves increase and decrease. In other words, the average width of the transparent portion of the sound track is decreased as the amplitudes of the waves decrease, resulting in a reduction of the reproduced noise due to dirt particles, scratches, *etc.*, on the surface of the film. The

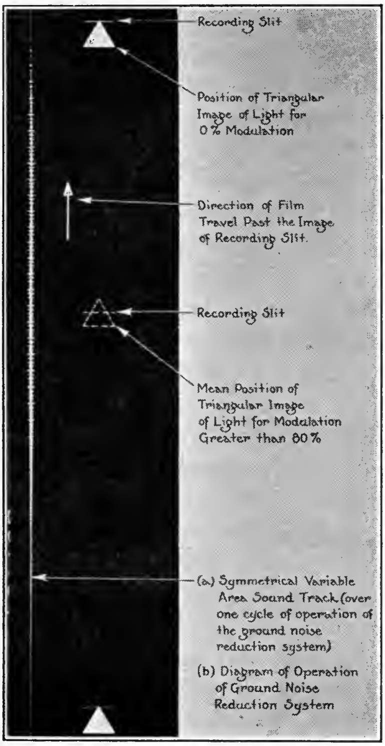


FIG. 30. Diagram showing nature of sound track and mean positions of triangular image of light or different degrees of modulation.

greatest reduction occurs at small amplitudes of modulation, when surface noises are most objectionable. At zero modulation, the center lines are spaced 2 mils (0.002 inch) apart, thus producing a 2-mil transparent band at the center of an otherwise opaque sound track. When the total of the amplitudes of the two waves is 80

per cent or more of the width of the sound track, the center lines of the waves are 35 mils apart. The speed of variation of the distance between the centers of the two sound waves, or the average transparent portion of the sound track, is so controlled as to prevent the introduction of audible disturbances into the reproduced sound. A rapid separation of these center lines occurs when a signal is impressed, while the closing takesplace relatively slowly after the signal wave ceases.

This method of reducing ground noise has the same advantage over the first system referred to as the second system does: namely, the clear portion of the sound print is in the center of the sound track. This prevents the loss or distortion of signals of small amplitude when the film is played on a reproducer whose scanning beam is so poorly adjusted that it does not completely scan the sound track, either because of improper adjustment or because of excessive weaving of the film. It is an improvement over the second system in that the modulating and darkening of the sound track are performed by a single moving element, the galvanometer, thus requiring no relative adjustment between two moving parts. A narrower transparent track may be used, and less extraneous modulation due to mechanical vibration is encountered, since the moving element, the galvanometer, is much stiffer than the shutter previously used. The present system requires careful damping of only one unit, the galvanometer; whereas the second system required very careful damping of both the galvanometer and the shutter or light-masking device. Damping of the latter was required, due to the fact that its resonance frequency was sufficiently low that, without damping, this unit could be shocked into resonance by changes in the biasing current. Also, the new system provides for completely controlling the required filtering and timing in the electrical circuit, rather than partly in the mechanical and partly in the electrical circuit.

In Fig. 30, (*b*) shows diagramatically the method of obtaining this type of sound track. A triangle of light is focused on a mechanical slit, an image of the slit being focused on the film. The recording galvanometer provides for moving this triangle of light at right angles to the axis of the slit, causing a change of width of the exposed part of the sound track. Two windings are provided on the galvanometer. One of these is a modulation winding, which causes the triangle of light to oscillate when electric waves are impressed. The other is an auxiliary, or bias winding, which, in conjunction with the ground

noise reduction amplifier, provides for shifting the triangle of light so as to maintain the minimum average width of clear sound track, after printing, without allowing the triangle of light to uncover the mechanical slit completely, when electric waves are impressed on the modulation winding. The solid triangles shown in the diagram represent the position of the triangle of light when no modulation is applied to the recording system. The dotted triangle represents the mean position of the triangle of light when its amplitude of vibration is equal to, or greater than, 80 per cent of full modulation of the sound track. For intermediate amplitudes of vibration, the mean positions of the triangle of light will always be between these two positions. The dotted triangle represents also the position of the triangle of light when neither bias nor modulation is supplied to the auxiliary

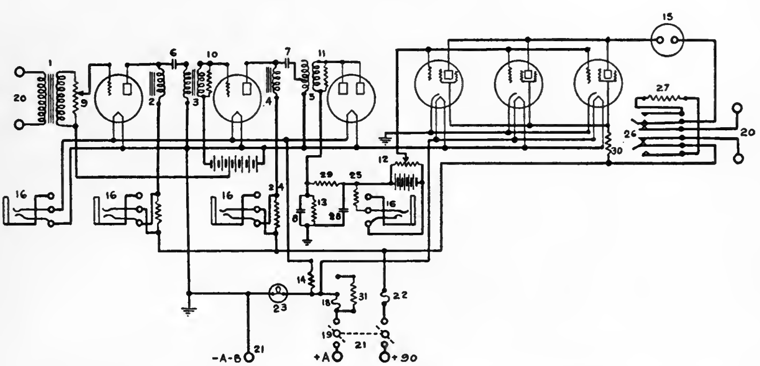


FIG. 31. Schematic diagram of ground noise reduction amplifier (*PA-71*).

or modulation windings, respectively. The initial biasing current required to shift the triangle of light from the dotted to the solid position, as shown in the diagram, as well as the variation of this biasing current with the amplitude of the sound wave, is supplied by the ground noise reduction amplifier.

Fig. 31 is a schematic diagram of the type *PA-71* ground noise reduction amplifier. Included in this unit are two stages of amplification, utilizing RCA-*112A* and RCA-*171-A* radiotrons in the first and second stages, respectively. The second stage (RCA-*171-A*) furnishes power to a *UX-280* rectifier, and a timing circuit composed of capacitors *8* and *28*, and resistors *13* and *29*. The timing circuit controls the rate of change of the rectified voltage used to bias the grids of the three RCA-*238* pentodes in parallel. The combined plate

current of these tubes is the biasing current used in the auxiliary winding of the galvanometer. By using three tubes it is possible to obtain sufficient biasing current, 27 milliamperes, from a 90-volt supply. It is desirable that this voltage be low, so as to require a minimum of insulation between the auxiliary winding and the ground, since the space available for such insulation is small. Also, a reduction in this voltage reduces the number of batteries required, as the plate supply for this amplifier is independent of that of the other units. The pentodes have a plate impedance sufficiently high so as not to impose an appreciable load on the modulation winding of the galvanometer due to the transformer action between the two windings of that unit. Otherwise, the change of plate impedance accompanying a change of the biasing current would cause modulation of the recorded signal.

Potentiometer *12*, Fig. 31, is used for adjusting the d-c. bias of the RCA-*238* radiotrons, so as to control the position of the triangle of light when no audio signal is supplied to the system. This "no signal" position of the triangle of light changes only slightly after it is once adjusted. Such changes are due to aging of the batteries or of the radiotrons, after extended use; however, they are in such a direction, decreasing the current, as to increase the width of the clear portion of the sound print, resulting only in a slight increase in the amount of ground noise reproduced. Even if the supply voltage of this unit were reduced to zero, the most serious consequence would be a normal recording without ground noise reduction. The audio input signal to the ground noise reduction amplifier is obtained from the drop of voltage in the 25-ohm resistor, which is in the 500-ohm input circuit of the recorder, due to the modulating current flowing in this circuit. This method of obtaining the input signal is used because the amplitude of vibration of the mirror is very nearly directly proportional to the modulating current, whereas the voltage across the modulation winding increases with frequency.

Potentiometer *9* controls the reduction of the biasing current and, accordingly, the shift of the triangle of light in relation to its amplitude of vibration. This control seldom requires adjustment. The time required to shift the triangle of light after a signal has been applied to the modulation winding, causing the triangle to vibrate, is the time that is required for the capacitors *28* and *8* to charge through the resistor *29* and the resistance of the rectifier. Transformer *5* has a step-down ratio such that the reflected plate im-

pedance of the radiotron *UX-171-A* is negligible as compared with that of the rectifier or of resistor *29*. The ratio of the capacitance of *8* to the resistance of the rectifier is such that 0.001 second is required to charge capacitor *8*. Capacitor *28* requires 0.006 second to charge through the resistor *29*, the resistance of the rectifier being negligible. The capacitance of *8* is large with respect to that of *28;* therefore, a signal of only 0.001 second's duration would completely charge capacitor *28* in 0.006 second after such a signal was impressed. In other words, capacitor *8* is completely charged in 0.001 second, and then discharges into capacitor *28* through resistor *29*, since the ratio of the resistance *13* to the capacitance *8* results in a discharging

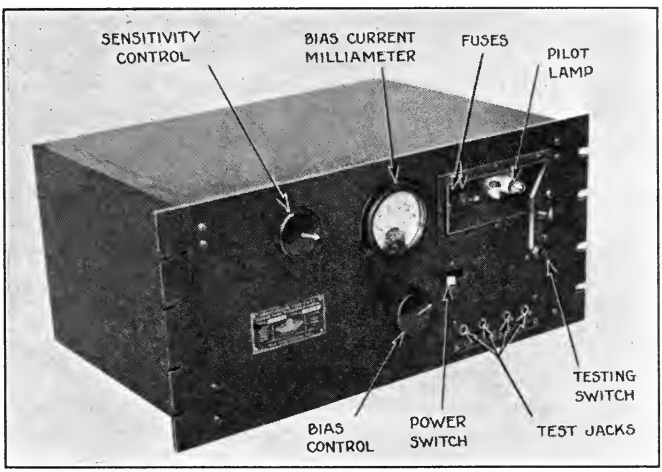


FIG. 32. Ground noise reduction amplifier (*PA-71*).

rate that is much slower than the charging rate of capacitor *28*. The time required to shift the triangle of light to the position of zero modulation, after the modulation has ceased, is 0.11 second, which is the total time required for capacitor *8* to discharge through resistors *13* and *29*. The two-stage timing circuit thus provides for controlling the filtering and the timing independently. The rate of increase of the clear portion of the sound track is sufficiently low to prevent audible disturbances such as "clicks" or "plops," and sufficiently rapid to prevent audible distortion due to "over-shooting." The rate of reduction of the transparent portion of the sound track

after the signal has ceased is slow enough to prevent second harmonic modulation and, at the same time, is sufficiently rapid to prevent an audible change in the hiss-to-signal ratio.

Meter *15* measures the bias current, which is supplied to the auxiliary winding through terminals *20*. Switch *26* is used to disconnect the auxiliary winding and to connect an equivalent resistor *27* across the output of the ground noise reduction amplifier to facilitate adjustments of the system. An oscillator is provided in the recording amplifier, as mentioned under the description of that unit, and furnishes a convenient source of 1000-cycle voltage for such adjustments.

The total voltage and current required are 6 or 8 volts and 3.8 amperes from the *A* supply, and 90 volts and 45 milliamperes from the *B* supply. Fig. 32 is a front view of the above-described amplifier.

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# A NEW PROCESS OF TELEVISION OUT OF DOORS*

A. T. STOYANOWSKY**

**Summary.**—*The problems involved in the transmission of motion pictures by television are, in general, less difficult to solve in certain respects than the problems in the television transmission of living subjects or objects in studios and, above all, out of doors. In the following article, a description is given of an interesting invention that changes the problems of television out of doors into corresponding problems of motion pictures by television.*

The experiments recently carried out in the various television laboratories of the Baird group have proved the possibility of transmitting images with sufficiently sharp detail to permit the expectation in the very near future of actual television in all of its applications.

We know that from now on, thanks to the experiments carried out upon the occasion of the Radio Exposition in Berlin by the Central Administration of the P. T. T. of the Reich, with a station transmitting on ultra-short waves (7 m., 15 kw.) and by means of motion picture transmitters of the Fernseh A. G., that the transmission of an image of 10,800 points (90 lines) with horizontal form 3 × 4 cms., 25 images per second, is an accomplished fact, and offers no further difficulties.

Although one may conceive of images of 19,200 points (120 lines), for which very satisfactory local transmissions have been effected, and even of 43,200 points (180 lines), it appears that *practical* television ought to attain a fineness of scanning of 20,000 points. In effect, the image obtained with this degree of detail is sufficiently sharp to satisfy the most exacting demands. The result thus obtained is comparable to the motion picture of today, if not in the detail effectively reproduced, at least in the quality of the image suggested.

The Fernseh A. G., which holds in Germany the rights of the Baird

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* Translated from the original in *La Technique Cinematographique*, **4** (Jan., 1933), p. 15.

** Director of Baird Natan Television.

group, publicly demonstrated in April, 1932, sending and receiving television apparatus using an image of 19,200 points.

The transmission was effected by means of a Nipkow disk 500 millimeters in diameter, with 120 hexagonal holes. The side of each hole is 0.05 millimeter. These holes are pierced in small pieces of gold foil supported by the disk. The sending was done with a motion picture transmitting apparatus with a Zeiss Ikon projector. The image projected on the disk was 9 × 12 millimeters. The transmitting disk had a single spiral, and revolved at 25 revolutions per second. The transmitting amplifiers comprised 8 stages.

The reception also took place on a Nipkow disk, by means of a sodium vapor lamp. This disk, of dimensions essentially equal to those of the sending disk, has a double spiral (Baird process).

By means of an optical system, the image was enlarged to about 7 × 10 centimeters. The brightness of this image is such that it can easily be observed in a slightly darkened room.

## TELEVISION TRANSMISSION OUT OF DOORS

An experiment was carried out by Baird Television, Ltd., upon the occasion of the Epsom Derby, in the course of which a picture was projected upon a screen several square meters in area in the Metropole Theater in London.

The transmission was effected by the aid of three cables, each of which carried an image of 2100 points at a rate of 12.5 images per second; but this complex system of transmission is somewhat limited with respect to the detail of the transmitted image. For the transmission of moving scenes, an image of 9000 points appears to be a limit that can not possibly be exceeded, even by the best technical means and in very clear weather if not in sunlight. In cloudy weather, it does not appear possible to effect the transmission of an image of more than 3000 to 4000 points. The difficulties are partly optical and partly due to the insufficient sensitivity of the cells.

To solve the problem, the Fernseh A. G. (licensee of Baird) has launched out into an entirely new direction in which, after many attempts and after surmounting many difficulties, they have attained an altogether remarkable result by means of the transmission of television with an intermediate film (Zwischenfilmsendung). The problem of scanning is, in effect, infinitely simpler for the transmission of motion pictures. A film presents neither depth of field nor color, and the most intense light may be used for illumination.

### TELEVISION TRANSMISSION BY FILM

A description of the apparatus as actually operated at the Radio Exposition in Berlin follows:

Fig. 1 gives the general arrangement of the apparatus represented in the photograph. The film used for taking the scene is contained in the magazine, *1*, and enters by a light-tight passage into a camera of a current model. The exposed film passes by a covered passage (with or without means of guiding) into a light-tight cabinet, *3*, containing the photographic solutions.

Once the film is developed and fixed, it passes into the television scanning apparatus, *5*. Then the film is rolled up on the drum, *6*. In Fig. 1, the film is indicated by *4*. The variations of potential effected in a photoelectric cell by the variations of brightness are amplified in the usual manner by the amplifier, *8*, and sent by the transmitter, *9*.

The possibility of the practical operation of the entire process

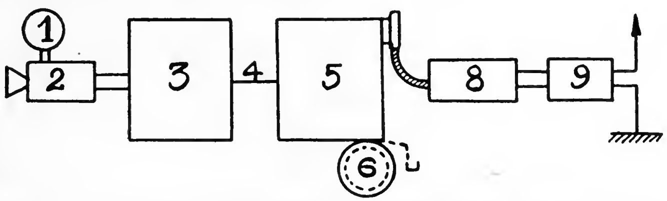


FIG. 1. Diagram of the television transmitter employing an intermediate film (*Fernsehen*, 1932, No. 3).

depends upon the minimum time necessary for the photographic processing. Assuming that 25 images per second are employed, and that the height of each image is 18 millimeters (standard film), a rate of motion of 0.45 meter per second is required for the film. If the photographic processing requires, for example, 3 minutes, it is necessary to pass into the cabinet, *3*, 81 meters of film before getting any results, which is a great disadvantage especially if the apparatus is to be portable. Even the use of a film of reduced dimensions hardly simplifies the problem.

From these considerations and to render the process practicable, it follows that it is necessary to reduce considerably the time necessary to develop and, *above all, to fix* the film. The attempts in this direction have been made in close collaboration with the motion picture section of the Zeiss Ikon A. G., Berlin-Zellendorf.

By the use of a special developer, it has been possible to reduce the time necessary for development to $^1/_2$ second. The reduction of the time of fixation is a much more difficult matter, but it has been possible to find, finally, a solution that requires no more than 24 to 30 seconds. Tests with incompletely fixed images were unsatisfactory, as the presence of a non-uniform layer gives rise to stains and spots.

After the manufacture of a special film which, moreover, is particularly sensitive, it has finally been possible to obtain total fixation in 4 to 5 seconds. In addition, it is helpful to insert, between the developer and fixing bath, a special solution that adds no more than $^1/_2$ second to the total time. Also, after the fixing bath, a supplementary bath or a short washing ($^1/_2$ second) is added.

In order to save time, this washing may be done after the scanning. Thus, the entire purely photographic process can be carried out in the astonishingly short time of 10 seconds. The negative thus obtained is of perfect photographic quality and may be used for printing a positive.

The water that remains on the film can be removed so uniformly that the scanning can take place without special precautions. After scanning, the still moist film is rolled without other precautions, upon a drum that is preferably kept in water. Ultimately, the film is washed and dried, and serves for the making of ordinary positives. The process has also the advantage, therefore, of permitting the further exploitation of a film that has served for the transmission of television.

Contrary to the usual method for sending motion pictures by television with a Maltese cross pull-down and spiral disks, in the apparatus described the film moves continuously. This is a necessity because (1) it is essential not to subject the still moist film to violent stresses; and (2) it is necessary to avoid risk of spattering the thin layer of water that covers the film, which spattering would involve optical difficulties.

Moreover, there is thus avoided the loss of 15 per cent in the height of the image due to the shutter necessitated by an intermittent movement. In this case, the holes of the exploring disk are not arranged in a spiral but in a circle.

The installation used at the Berlin Exposition operated with 90 lines, corresponding to 10,800 points. The diameter of the scanning disk was 500 millimeters; the scanning holes are regular hexagons

0.09 millimeter on a side. It goes without saying that, apart from the great precision necessary in the construction of the disk, it is equally necessary to attain a high degree of precision in the movement of the film, which is effected in a perfectly uniform manner without the appearance of any distortion in the image.

The electrical and optical parts of the apparatus are represented diagrammatically in Fig. 2. The light source, *1*, is an incandescent lamp, the filament of which is projected by the lenses, *2*, upon the disk, *3*.

The image of the filament is a straight line, whereas the path of the opening in the disk is a very slightly curved arc of a circle; but, since the diameter of the hole is only 0.156 millimeter, a greatly enlarged image of the filament may be formed, under the best conditions of

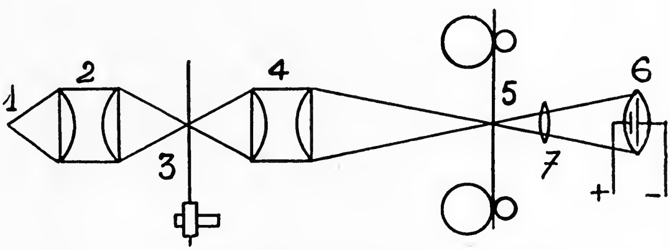


FIG. 2. Diagram of the electroöptical system of the sending apparatus.

illumination, which uniformly covers the opening in the disk over its entire course.

The incandescent lamp is lighted by continuous current (10.5 volts, 15 amperes), and consumes less than 160 watts, which is not excessive in view of the extreme enlargement necessary. The image of the scanning hole is projected by the objective, *4*, upon the film, *5*, which moves continuously. If desired, it is possible to provide a condenser between the cell, *6*, and the pupil of light scanning the film.

The driving of the scanning disk and the movement of the film are effected by means of two separate synchronous motors (1500 rpm.) actuated by the same alternating current, and consequently perfectly synchronized. The movement of the film is continuous in the entire apparatus, excepting in the camera, which is of the ordinary type. However, the movement in the camera must be synchronized with the continuous movement of the film.

This is accomplished by means of a flexible shaft between the camera and the motor driving the film for scanning. It is not necessary to regulate the phase of the motor driving the film with respect to the scanning, since the scanning is done with a disk with holes arranged in a circle. If, on the other hand, an intermittent movement

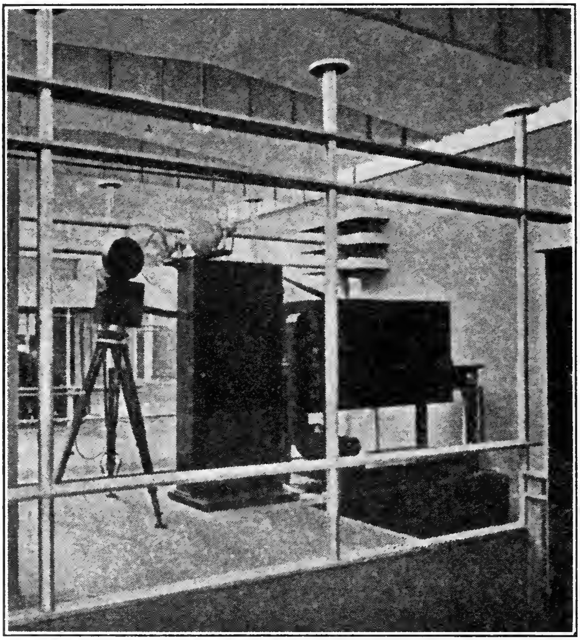

Fig. 3. The intermediate film transmitter shown in this photograph permits taking any event with the motion picture camera, develops the exposed film, and transmits the film by television with a detail of 10,800 image points at a rate of 25 images per second. The image can be transmitted 15 seconds after being photographed.

of the film is employed with a spiral disk, it is necessary to provide a precise adjustment of phase.

In the developing and fixing baths, no sprockets are found, but only guide rollers which are turned in synchronism with the scanning motor. For the movement of the 5-meter length of film that is in the various parts of the apparatus at a given instant, the guide rollers suffice. The scanned film is rolled upon the drum by means of an ordinary motor (non-synchronous) through a friction coupling.

If the film in the camera magazine is exhausted, the motor that drives the camera is automatically stopped so that a new roll of film may be spliced on before the entrance to the machine, thus avoiding rethreading of the film through all the guides. Taking scenes in the studio or out of doors is done with an ordinary camera under ordinary conditions.

The amplification is effected in the usual manner with an amplifier of 8 stages. The apparatus functions, in spite of its provisional construction, in a continuous and certain manner, and permits transmission, with 10,800 image points of anything that may be taken with a camera, independently of the aperture of the taking lens.

The new transmitter appears at first sight to have one decided disadvantage. Although it is immaterial if the television amateur sees events transmitted with a delay of 10 seconds, this delay would become intolerable if the sound were transmitted simultaneously. But this disadvantage can be avoided very easily if the sound is recorded on the same film as the image, developed at the same time, and then transmitted at the time at which the television scanning takes place. This intermediate recording of the sound can obviously take place on a separate film or by any other known process of recording.

The described apparatus can be improved in a number of ways. It should not be difficult, for example, to send a picture of 20,000 image points. It is equally possible to reduce further the time interval between the taking of the scene and the reproduction by reducing the time necessary for the photographic manipulations. The apparatus could be mounted in such a manner as to be easily portable if this should prove useful. The connection between a movable television truck and the principal radio sending station could be effected by means of an ultra-short wave transmitter in order to be directional, if cables or ordinary overhead wires can not be considered, thereby giving a broader band of transmission frequencies.

For the practical operation of this process, we shall meanwhile await the solution of another technical problem, namely, the transmission and reception of radiovision broadcasting on ultra-short waves. The Baird group is actively studying this question and the results already obtained are very encouraging.

# BOOK REVIEWS

**Architectural Acoustics.** V. O. KNUDSEN. *John Wiley and Sons,* New York, N. Y., 1932, viii + 617 pp., $6.50. This book is a comprehensive treatise on the subject of architectural acoustics. It contains not only the results of the author's own researches but also brings into one volume a general summary of the latest developments in the field. It is so arranged that it should fulfill a long-felt need for a text for university students, and at the same time serve as an invaluable reference for the acoustical engineer.

The book contains three main parts. Part one, on physical and physiological acoustics, is so presented that even though the reader is not trained in the theory of sound he should obtain a fair acquaintance with the fundamental principles necessary for an adequate comprehension and appreciation of the fundamentals of architectural acoustics. The second part of the book contains a thorough discussion of problems of reverberation, sound absorption, transmission, and insulation of sound. Included in this part are tables giving the acoustical and physical properties of a large number of materials. These tables, which are arranged according to the general characteristics of the materials, are probably the most complete and extensive of any so far published. The third part of the book is a discussion of the application of the theory and principles of architectural acoustics to practically all types of buildings. A list of problems is included at the end, which should increase the value of the book as a text.

Dr. Knudsen has in the publication of this book made a contribution to the field of architectural acoustics that will be of value both to the student and to the engineer.

R. L. HANSON

**Acoustics and Architecture.** P. E. SABINE. *McGraw-Hill Book Company, Inc.,* New York, N. Y., 1932, vii + 321 pp., $3.50. The phases of acoustics that are directly applicable to architectural problems make up the subject matter of this book. It has been prepared especially for architects and others interested in the practical aspects of the subject. The author, who has had many years of experience in the subject, both inside and outside the laboratory, has chosen to present the material in a way useful to a non-mathematical reader.

Acoustics is one of the oldest branches of physics, and relatively tremendous advances in the subject have been made during the last fifteen years. But in spite of this, it is still in some respects an inexact science. Theoretical investigations and the collection of practical data along many lines are desirable. In pointing out the necessity for more accurate information on the one hand, however, the author emphasizes on the other hand that from a practical point of view it is no longer necessary to be doubtful that the acoustical properties of a projected auditorium will be tolerable.

Two-thirds of the book deal largely with the acoustics of auditoriums, and treat of the properties of sound, reverberation, and sound absorption. The latter third is devoted to noise in buildings and sound transmission through and in build-

ing structures. Throughout the book emphasis is placed on experimental data, in a large part obtained by the author at the Riverbank Laboratories. It might be suggested that in the preface is to be found excellent advice to one attempting to gain insight into the present state of practical acoustics. W. A. MACNAIR

**Radio Engineering Handbook.** Edited by K. HENNEY; written by a corps of twenty-two engineers specialized in the various branches. *McGraw-Hill Book Co.*, New York, N. Y., 1933, 583 pp., $5.00. Although one might wonder at first thought why the review of a *radio* engineering handbook should appear in a journal devoted primarily to motion picture engineering, the identity of many subjects in both branches of engineering justifies its appearance. Motion picture engineering is an integration of a number of arts: excepting the mechanics and the chemistry of motion picture engineering, the subjects of electrical transmission, electroacoustical recording and reproducing, photoelectricity, electrical measurements, *etc.*, are common to radio and motion pictures. A topical résumé of the sections of the handbook in which motion picture engineers would be interested will illustrate: Electric and Magnetic Circuits; Resistance; Inductance; Capacity; Complex Electrical Circuit Theory; Measuring Instruments; Vacuum Tubes; Modulation; Audio Frequency Amplifiers; Rectifiers and Power-Supply Systems; Loud Speakers and Acoustics; Television; Facsimile Transmission; Photoelectric Cells; and finally, a section on Sound Motion Pictures, written by F. S. Irby.

The style of the work is typical of handbooks, the material being arranged primarily for reference through the fairly extensive index provided. The handbook undoubtedly fills a long-felt need of engineers for a reference source in the subjects listed above. S. HARRIS

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# SOCIETY ANNOUNCEMENTS

## NEW YORK CONVENTION, APRIL 24–28, 1933

The semi-annual convention of the Society was held in New York, N. Y., April 24th–28th, with headquarters at the Hotel Pennsylvania. The success of the-five-day meeting was due in large part to the efforts of Mr. W. C. Kunzmann, chairman of the Convention Arrangements Committee; Mr. O. M. Glunt, chairman of the Papers Committee, and his associates; and to the following individuals and firms:

Mr. H. Griffin and Mr. H. Heidegger, of the International Projector Corp., for providing and installing the projection equipment; Mr. A. L. Raven, of the Raven Screen Corp., for supplying and installing the projection screens; the Bausch & Lomb Optical Co., for the projection lenses; the Blue Seal Sound Products, Inc., for supplying the projection booth for the banquet hall; Messrs. J. H. Spray and H. Mayer, of Warner Bros. Pictures, Inc., for providing entertainment on the evening of the semi-annual banquet. Thanks are due Major Edward Bowes, of the Capitol Theater; Mr. H. B. Franklin, of Radio City Music Hall; Mr. H. Charnas, of Warner Bros. Strand Theater, for invitations kindly extended to members of the Society to visit their respective theaters during the week of the convention. Interesting film programs were provided for three evenings at the hotel by the following companies: Columbia Pictures Corp., Fox Film Co., Metro-Goldwyn-Mayer, Inc., United Artists, Inc., Universal Pictures Corp., Mr. W. J. Vanderbilt, and Warner Bros. Pictures, Inc. Credit is due also to Mrs. E. I. Sponable for arranging an interesting program for the ladies attending the convention.

At the luncheon which opened the convention on April 24th, addresses were delivered by Mr. Terry Ramsaye, of the *Motion Picture Herald;* Mr. M. A. Lightman, president of the M. P. T. O. A.; and Captain Paul Kimberley, of England, bearer of a friendly message from the president of the British Kinematograph Society to the Society of Motion Picture Engineers.

## PROGRAM

### MONDAY, APRIL 24TH

The morning was devoted to organization of the Convention, registration, meetings of committees, *etc.*

**12:30 P. M. Luncheon** (for members and their families and friends).

Speakers: Mr. Terry Ramsaye, Mr. M. A. Lightman, Captain Paul Kimberley (*London*).

**2:30 P. M. Business Session.**

Opening of Convention; A. N. Goldsmith, *President.*

Report of the Secretary, J. H. Kurlander.

Report of the Treasurer, H. T. Cowling.

Report of the Convention Arrangements Committee; W. C. Kunzmann, *Chairman.*
Society Business.

**3:00 P. M. General Session.** PRESIDENT A. N. GOLDSMITH, *Chairman.*

"Application of Motion Picture Development in Other Fields;" O. H. Caldwell, *Electronics*, McGraw-Hill Publishing Co., New York, N. Y.

"History of Animated Cartoons;" E. Theisen, *Honorary Curator*, Motion Picture Collections, Los Angeles Museum.

"The Sound Film Program of the United States Department of Agriculture;" R. Evans, Division of Motion Pictures, Department of Agriculture, Washington, D. C.

"Audiphone—'Out of the Silence;'" C. W. Barrell, Western Electric Co., New York, N. Y.

**8:00 P. M. Lectures.** PRESIDENT A. N. GOLDSMITH, *Chairman.*

"Unoccupied Motion Picture Fields" (Some Discoveries of the Payne Fund Research); W. H. Short, *Director*, Motion Picture Research Council, New York, N. Y.

"Photoplay Appreciation in the Nation's Schools;" W. Lewin, National Council of Teachers of English, Newark, N. J.

Several interesting talking motion pictures were shown.

**TUESDAY, APRIL 25TH**

**9:30 A. M. Studio Session.** MESSRS. E. I. SPONABLE AND J. H. KURLANDER, *Chairmen.*

"RCA Victor High Fidelity Film Recording Equipment;" S. Read, Jr., RCA Victor Co., Camden, N. J.

Report of the Progress Committee, Part I; J. G. Frayne, *Chairman.*

Report of the Studio Lighting Committee; P. Mole, *Chairman.*

Report of the Sound Committee; H. B. Santee, *Chairman.*

"The Preselection of Takes for Processing from Exposed Undeveloped Negative;" D. W. Ridgway, RKO Studios, Hollywood, Calif.

"Professional Motion Picture Photography with High-Power Short-Life Incandescent Lamps;" M. W. Palmer, Motion Picture Lighting Co., Long Island City, N. Y., and E. W. Beggs, Westinghouse Lamp Co., Bloomfield, N. J.

"Economies in Film Consumption by the Preselection Method;" G. Best, Warner Bros. West Coast Studios, Hollywood, Calif.

**2:00 P. M. Exhibition Session.** MR. E. HUSE, *Chairman.*

"Radio City Sound Equipment;" B. Kreuzer, RCA Victor Co., Camden, N. J.

Report of the Progress Committee, Part II; J. G. Frayne, *Chairman.*

Report of the Projection Theory Committee; A. C. Hardy, *Chairman.*

Report of the Projection Screens Committee; S. K. Wolf, *Chairman.*

"A New AC Projection Arc;" D. B. Joy and A. C. Downes, National Carbon Co., Cleveland, Ohio.

"Avoidance of Eye Fatigue;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y.

"Wide-Screen Photography with Cylindrical Anamorphosing System;" H. S. Newcomer, Consulting Engineer, New York, N. Y.

"The Morgana Color Process;" J. A. Dubray, Bell & Howell Co., Hollywood, Calif.

"Sound Recording and Reproducing Using 16-Mm. Film;" C. N. Batsel and J. O. Baker, RCA Victor Co., Camden, N. J.

**8:00 P. M.** This evening was left open for visits to local theaters.

**WEDNESDAY, APRIL 26th**

**9:30 A. M. Photographic Session.** MR. T. E. SHEA, *Chairman.*

"Sound Film Printing;" J. Crabtree, Bell Telephone Laboratories, Inc., New York, N. Y.

"Sensitometric Control in the Processing of Motion Picture Film in Hollywood;" E. Huse, Eastman Kodak Co., Hollywood, Calif.

"The Eastman *IIb* Sensitometer as a Control Instrument in the Processing of Motion Picture Film;" G. A. Chambers and I. D. Wratten, Eastman Kodak Co., Hollywood, Calif.

"Some Properties of Two-Bath Developers for Motion Picture Film;" J. I. Crabtree, H. Parker, and H. D. Russell, Eastman Kodak Co., Rochester, N. Y.

"An Improved Potassium Alum Fixing Bath Containing Boric Acid;" H. D. Russell and J. I. Crabtree, Eastman Kodak Co., Rochester, N. Y.

"Directional Effect in Processing;" J. Crabtree, Bell Telephone Laboratories, Inc., New York, N. Y.

**2:00 P. M. Projection Session.** PRESIDENT A. N. GOLDSMITH, *Chairman.*

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

"Image Distortion in the Projection and Viewing of Motion Pictures;" C. Tuttle, Eastman Kodak Co., Rochester, N. Y.

**7:00 P. M. Convention Banquet.**

Dancing, Motion Pictures, and Entertainment.

**THURSDAY, APRIL 27th**

**9:30 A. M. General Session.*** PRESIDENT GOLDSMITH presented MR. J. I. CRABTREE, *Chairman.*

Address of Welcome, by E. H. Colpitts.

"Recent Developments in Hill and Dale Recording" (with demonstration); H. C. Harrison, Bell Telephone Laboratories, Inc., New York, N. Y.

"An Experimental Apparatus for the Projection of Motion Pictures in Relief" (with demonstration); H. E. Ives, Bell Telephone Laboratories, Inc., New York, N. Y.

Report of S. M. P. E. Fellow; "An Introduction to the Experimental Study of Visual Fatigue;" P. Snell, University of Rochester.

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* This session was held in the auditorium of Bell Telephone Laboratories, Inc.

**2:00 P. M. Standardization Session.** MR. T. E. SHEA, *Chairman.*

"National Standardization in America;" P. G. Agnew, *Secretary*, American Standards Association, New York, N. Y.

"S. M. P. E. Standardization Program;" L. A. Jones, Eastman Kodak Co., Rochester, N. Y.

Report of the Standards Committee; M. C. Batsel, *Chairman.*

"Wave Form Analysis of Variable Width Records;" O. Sandvik, V. C. Hall, and J. G. Streiffert, Eastman Kodak Co., Rochester, N. Y.

"Analysis of Sound Quality with the Variable Density Method from Sensitometric Data;" R. Schmidt and A. Kuester, Agfa Ansco Corp., Binghamton, N. Y.

"The Aperture Alignment Effect;" E. D. Cook, RCA Victor Co., Camden, N. J.

**8:00 P. M.** Exhibition of recent talking motion pictures.

### FRIDAY, APRIL 28TH

**9:30 P. M. General Session.** MR. T. E. SHEA, *Chairman.*

Report of the Committee on Non-Theatrical Equipment; R. E. Farnham, *Chairman.*

"The Reproduction of Orchestral Music in Auditory Perspective;" J. Mill, Bell Telephone Laboratories, Inc.

"Personality and the Voice;" Ivah L. Bradley, New York, N. Y.

"A Description and Demonstration of the Ciné-Kodak Special;" O. Wittel, J. Stoiber, and F. Tuttle, Eastman Kodak Co., Rochester, N. Y.

"Motion Pictures for Records and Teaching with the Ciné-Kodak Special;" H. B. Tuttle, Eastman Kodak Co., Rochester, N. Y., and R. P. Schwartz, University of Rochester.

Report of the Museum Committee; E. Theisen, *Chairman.*

Report of the Committee on the Preservation of Film; W. H. Carson, *Chairman.*

"A Non-Intermittent High-Speed 16-Mm. Camera;" F. Tuttle, Eastman Kodak Co., Rochester, N. Y.

"Lightweight Single Film Recording System for Newsreels and Travelogues;" C. R. Sawyer, Electrical Research Products, Inc., New York, N. Y.

**2:00 P. M. General Session.** PRESIDENT A. N. GOLDSMITH, *Chairman.*

"New Developments in Portable Gas-Electric Generators for Motion Picture Lighting;" P. Mole, Mole-Richardson, Inc., Hollywood, Calif.

"Silenced or Silent Motion Picture Camera;" H. R. Kossman, André Debrie, Inc., New York, N. Y.

"Military Training and Historical Films;" F. W. Hoorn, U. S. Signal Corps.

"A Triplex Moviola for Rerecording Editing;" J. Aalberg, RKO Studios, Hollywood, Calif.

"Recording Equipment;" D. Canady, Canady Sound Appliance Co., Cleveland, Ohio.

## BOARD OF GOVERNORS

At the Board meeting held at the Hotel Pennsylvania, New York, N. Y., on April 23rd, final arrangements for the Spring Convention, to begin the following day, were completed. The final program as approved by the Board is given in the preceding section.

Considerable attention was given by the Board to the various financial problems confronting the Society, and the desirability of revising the schedule of membership charges. In view of the existing economic situation, it seemed to be desirable that a certain degree of flexibility be allowed the Board in administering the fiscal affairs of the Society and to admit of adjusting the dues and other charges conformably to the changing conditions of the times. The following addition to By-Law VII was therefore framed for submission to the general membership during the Convention:

### *Addition to By-Law VII*

**Sec. 7.** *The provisions of Sections 1 to 5, inclusive, of this By-Law VII, given above, may be modified or rescinded by action of the Board of Governors.*

At the meeting of the Society on the afternoon of Monday, April 24th, the above addition to By-Law VII was unanimously approved.

The Sections 1 to 5, referred to in this new Section 7, are as follows:

SEC. 1. The entrance fees for all applicants shall be $10.00 for admission to the grade of Active member, and $5.00 for admission to the grade of Associate member.

SEC. 2. The transfer fee from Associate to Active grade shall be the difference between the above mentioned fees, or $5.00.

SEC. 3. The annual dues shall be $20.00 for Active members, and $10.00 for Associate members, payable on or before October 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a quarterly basis, said quarters beginning October 1st, January 1st, April 1st, and July 1st. Nine dollars of these dues shall apply for annual subscription to the monthly publication.

SEC. 4. Annual dues shall be paid in advance. All Active members in good standing, who shall have paid dues for the preceding year, may vote or otherwise participate in the meeting.

SEC. 5. Members shall be considered delinquent whose dues remain unpaid for four months. Members who are in arrears of dues for 30 days after notice of such delinquency, mailed to their last address of record, shall have their names posted at the Society's headquarters which shall be the General Office, and notices of such action mailed them. Two months after becoming delinquent, members shall be dropped from the rolls if non-payment is continued.

A general discussion of the activities of the various committees of the Society was held, in preparation for the joint meeting of the Board of Governors and chairmen of committees to be held the following day, and described below. With regard to the recent request of the Committee on the Development and Care of Film that the name of the committee be changed in order that it be more descriptive of the aims and functions of the Committee, the Board agreed that the Committee should hereafter be known as the Committee on Laboratory and Exchange Practice. Considerable discussion was also held concerning the possibility of widely distributing among exchanges and exhibitors the test film developed under the supervision of the Projection Practice Committee, presented at this Convention in conjunction with the report of that Committee, and briefly described in the Society Announcements sections of previous issues of the JOURNAL.

The next meeting of the Board is to be held on July 14th.

## SUSTAINING MEMBERS

Bausch & Lomb Optical Co.
Bell Telephone Laboratories
Burnett-Timken Laboratories
Eastman Kodak Co.
Electrical Research Products, Inc.
National Carbon Co.
RCA Victor Co., Inc.

## HONOR ROLL

OF THE

## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

# JOURNAL

OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

**Volume XX** **JUNE, 1933** **Number 6**


*CONTENTS*

# JOURNAL
## OF THE SOCIETY OF
# MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR




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Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

# PROGRESS IN THE MOTION PICTURE INDUSTRY*

***Summary.***—*This report of the Progress Committee covers the period June, 1932, to May, 1933. The advances in the cinematographic art are classified as follows: (I) Cinematography, (II) Sound Recording, (III) Sound and Picture Reproduction, (IV) Film Laboratory Practice, (V) Applications of Motion Pictures, (VI) Publications and New Books, (VII) Appendix.*

In spite of the economic paralysis of the country during 1932, the motion picture industry has steadily made progress. While it is true that no spectacular advances can be reported for the past year, there are numerous items showing progress in every branch of the motion picture art. It is especially interesting to note that some of the major items of progress during the past year have been in the amateur field. This should augur well for the future of the industry because it has been demonstrated time and again that an art that is supported by an interested amateur element is sure to progress.

Some new film emulsions were announced during 1932, the most interesting in the professional field being a new panchromatic film possessing a high green sensitivity. The introduction of the 8-mm. film in the amateur field called for a very fine-grained emulsion, which has been satisfactorily used now for approximately a year. In the field of sound recording were introduced new emulsions of greater speed than the standard positive films heretofore used almost exclusively in this kind of work.

Progress continued to be made during the year in the design of new cameras, both professional and amateur. One company has recently demonstrated to the industry a new silent camera embodying many new and novel features. If this camera proves to be as good as the claims made for it, it should rid the motion picture industry of one of the severe limitations imposed upon it by the talking picture; namely, the use of "bungalows" and "blimps" and other undesirable attachments to a camera to make it sufficiently quiet in operation on the stage.

During the past year considerable progress has been made in the

* Report of the Progress Committee. Presented at the Spring, 1933, Meeting at New York, N. Y.

use of transparent projected background processes. Some of the most popular films released during the year contained a large percentage of shots made in this manner. There has been a tendency during the past year to substitute some accurate means of measuring exposure on stages to replace the guesswork of the cameraman in estimating the intensity of illumination of sets. An interesting development in colored motion pictures during the year was the application of color to cartoons. In the amateur field, the introduction of the 8-mm. film with the consequent reduction in the cost of making amateur movies has tended to popularize the art more than ever. The introduction of a rather simple additive color process in this field has also widened the possibility of the use of color by the amateur. Some progress has been reported in 16-mm. sound film during the year, and certain standardizations in this field have been agreed upon by the interested companies.

In the field of sound recording and reproduction, considerable attention has been given during the past year to extending the range of frequency of reproduced sound, the object being to achieve greater fidelity of reproduction. While the introduction of the newer equipment in studios and theaters has been delayed by economic difficulties, it is expected that during this year great improvement will occur in the quality of sound reproduced from film.

The application of motion pictures has advanced considerably during the year in connection with scientific research, educational work in schools and colleges, and timing devices of a high order of accuracy.

There has been a considerable decrease in the use of dubbed foreign versions for American pictures. Instead, American motion picture companies have been developing their production abroad in order to produce films in the native languages. The restrictions in certain European countries against American films have been lessened or considerably modified in various countries during the past year, and the field for American motion pictures seems to be limited only by the ability of the producers to make films of a sufficiently wide appeal for the various peoples of the earth. The Society of Motion Picture Engineers is naturally interested in the status of the motion picture in Russia, where the industry has, of course, received sponsorship from the Soviet Government, and a special section of this report deals with the condition of the industry in that country.

The Committee wishes to thank the various individuals and con-

cerns that have supplied material for this report, and regrets that all the institutions connected with the motion picture industry did not see fit to supply information on their various contributions to the art during the past year.

The illustrations shown in the report were obtained from the Bell & Howell Co., Eastman Kodak Co., Electrical Research Products, Inc., General Electric Co., Ltd., RCA Victor Co., Inc., Weston Electrical Instrument Corp., Western Electric Co., and Paramount Publix Corp.

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## SUBJECT CLASSIFICATION

### CINEMATOGRAPHY

*A. Professional*

1. New Films and Emulsions
2. New Cameras and Accessories
3. Studio Illumination
4. Exposure Meters
5. Color

*B. Amateur*

1. General
2. New Emulsions
3. Cameras and Projectors
4. Color

### II. SOUND RECORDING

1. General
2. New Recording Equipment
3. New Recording Methods
4. Microphones
5. Motor Systems
6. Accessories

**III. SOUND AND PICTURE REPRODUCTION**

1. New Sound Equipment
2. New Projectors and Accessories
3. 16-Mm. Sound-on-Film

**IV. FILM LABORATORY PRACTICE**

1. Film Development
2. Printers
3. Editing

**V. APPLICATIONS OF MOTION PICTURES**

1. Education
2. Race Timing Devices

**VI. PUBLICATIONS AND NEW BOOKS**

**VII. APPENDIX**

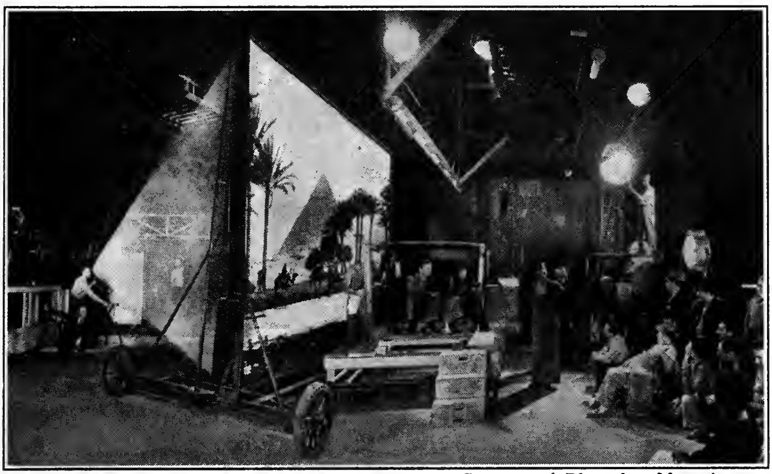
## I. CINEMATOGRAPHY

### *A. Professional*

1. *New Films and Emulsions.*—Two years have passed since the new fast panchromatic negative emulsions were first introduced. These materials are characterized by their fineness of grain, improved color sensitivity, and increased speed, especially to incandescent illumination. Sheet films were made available about the same time for the still photographer. These were of two types: (*a*) a panchromatic film of high total sensitivity and extreme red speed, and (*b*) an "orthopanchromatic" film having a color-sensitivity corresponding closely to that of the eye. The high-speed panchromatic emulsions introduced in 1931 for motion picture use were all of the former type and are satisfactory for most purposes, both for interior and exterior work. Occasionally it was found, however, that with certain close-ups there was a tendency for over-correction in the red which caused a false rendering of the flesh tones, particularly of the lips. An emulsion was, therefore, introduced during the summer of 1932 that had properties similar to those of the second type of sheet film emulsion. It is said to possess high green sensitivity between 500 and 560 m$\mu$ and a reduced red speed compared with the regular high-speed panchromatic ciné negative materials.[1] The cameraman is thus equipped now with a panchromatic emulsion of the portrait type corresponding to that used by the portrait photographer.

Several films for recording sound by both the variable density and the variable width methods were introduced during the past year that exhibited improved speed characteristics.[2]

Bloch[3] summarized the recent advantages in emulsion making. Several factors related to the cause of high sensitivity and fine grain in modern panchromatic emulsions were summarized by Fuchs,[4] and details from patents were given concerning the newer cyanine dyes. Stabilization and control of fog were shown to be effected by the introduction of certain thiazoles and imidazoles during manufacture.[5]



*Courtesy of Photoplay Magazine*

FIG. 1. Illustrating the use of composite photography in *The Mummy*.

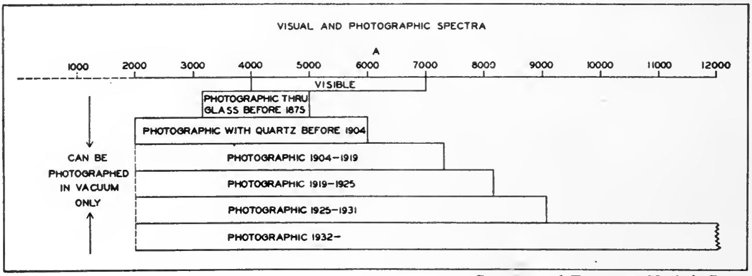
Greater attention has been given during the past few years to the testing of photographic emulsions, perhaps, than ever before, due to the more exacting requirements of the studios. In keeping with this trend, Baker[6] has outlined various methods of testing, and has described apparatus used with particular reference to motion picture work.

The increased use (Fig. 1) being made of the transparent projected background process noted in last year's report has resulted in the introduction of a special negative material for photographing the scene to be used for the background. It is said to have very fine grain and about the same speed and contrast as the regular

negative film. About 65 per cent of the scenes in the Fox feature *State Fair* were made by this process.

A double matte process for the introduction of foreground action before a suitable background has been described by Williams, and is stated to be a refinement of a process patented by him in 1918. A dye-coated supersensitive panchromatic film is used in a bi-pack, arranged emulsion to emulsion with another supersensitive panchromatic film. The actors are illuminated in the usual manner before a blue background. Prints from the front negative are developed and edited for selection of the scene to be used with the background scene. The matte made from this print and the corresponding back negative is used for printing in the action in the usual way.[7]

For making duplicate negatives, Crabtree and Schwingel[8] recommend developing the master positive to a relatively high contrast




*Courtesy of Eastman Kodak Co.*

FIG. 2. Illustrating advance of photography into infra-red region of spectrum.

(gamma = 1.85) and the duplicate negative to a low contrast (gamma = 0.55) in order to insure low graininess in the final print. Prints made from duplicate negatives of sound records were said to be practically indistinguishable from original prints, although frequency records showed some loss above 5000 cycles and a slight increase of surface noise.

The greatest spectral extension of photographic sensitiveness in the past quarter century occurred in 1932, as illustrated in Fig. 2. Spectroscopic lines in the infra-red were recorded as far as 12,300 Å by Meggers of the U. S. Bureau of Standards. The list of specially sensitized plates mentioned last year has been extended recently by Mees.[9] The chemical structures and spectra of infra-red sensitizing dyes have been described by Brooker, Hamer, and Mees.[10] Several

additional papers on photographic emulsions were published by Carroll and Hubbard[11] of the U. S. Bureau of Standards, the most recent one dealing with variables in dye sensitizing.

Patents relating to emulsion manufacture disclosed among other features a process of applying a color filter, which may later be destroyed chemically, to an emulsion surface; a method of tinting the picture areas of a sound and picture film, leaving the sound track area untinted; and a method of coating a permanently translucent light diffusing material between a slow sensitive and a fast silver halide layer.[12] Several other patents were issued relating to the important subject of halation prevention.[13] Processes using diazo compounds as light-sensitive materials instead of silver salts continued to interest inventors but have thus far had very limited practical application.[14]

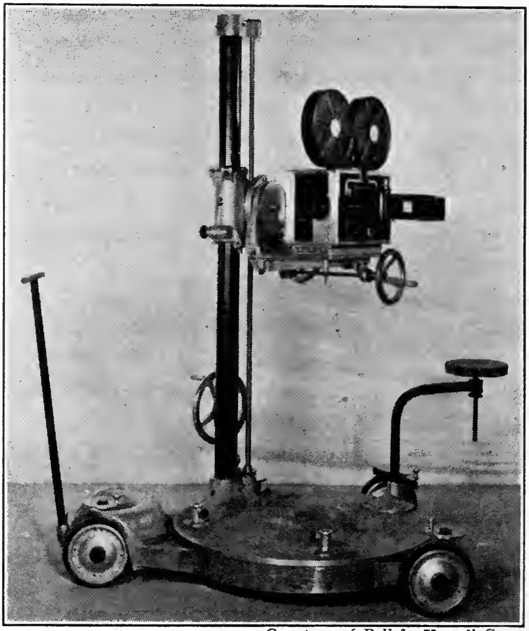
A patent was issued to Kupfer, whose metallic film bands were mentioned in last year's review. The present disclosure describes methods of reclaiming used film bands by removing the gelatin-silver layers from the metal support.[15]

2. *New Cameras and Accessories.*—An entirely new professional 35-mm. camera, said to operate silently, has been announced by the Bell & Howell Co. (Fig. 3.) The film movement is of the type employing two stationary registering pilot pins. The change from the focusing to the operating position is accomplished by means of a rapid-acting lever which controls the positioning of a ground glass at the taking aperture, thus eliminating shifting of the camera.

The mounting of the lenses is unique in so far as the focusing is controlled by a single knob at the rear right of the camera and only one focusing dial is required for all lenses of focal lengths varying from 24 to 150 millimeters. During focusing, the lens remains stationary and the proper motion is imparted to the film mechanism itself.

The design of the camera view finder is completely new, correction being provided automatically for differences of parallax, and for automatically correlating the adjustment of the finder lens with the focusing of the photographic lens. The finder's field of view can be adjusted with great precision to correspond to that of the taking lens. The maximum aperture of the shutter is 180 degrees, and it can be adjusted to lower apertures. The driving motor operates on 48-cycle 220-volt 3-phase current, runs cool and silent, and is enclosed in the camera case.[16]

A sound camera of French make (*Eclair*) is claimed to be noiseless and has the main sprockets of the picture and sound mechanisms mounted on the same shaft, the driving motor being located in the middle of the case between the sound and the picture heads. Thousand-foot individual retort-type external magazines are used. A four-lens turret is provided, but the focusing scale can be calibrated for ten lenses, while a prismatic magnifying tube allows focusing on the film.[17]



*Courtesy of Bell & Howell Co.*

FIG. 3. New Bell & Howell silent camera.

A new camera (Tally's, of Los Angeles) embodies many unusual features. The sprockets are not contained in the camera, but form part of the light trap mechanism of the 1000-foot magazines (with hinged covers) mounted below the camera body. Advantage is taken of the lowered center of gravity by the pam-and-tilt movement built as an integral part of the camera head, which is so balanced that it will remain stationary in any position. The cam and shuttle movement with pilot pin is said to be so silent that the camera does

not require additional covering to dampen its running noises. Focusing is accomplished by moving the entire four-lens turret, and is followed on a ground glass inserted by levers into the film plane. There is sufficient space for installation of a recording lamp and the camera may be driven by any type of studio motor.

A new silent camera is made in Great Britain by W. Vinten, Ltd. (Fig. 4), in which a claw and registering pin movement, driven from one crank shaft, has eliminated cams and cam slots. The film gate with film in place is moved away from the aperture part for focusing. The threads of the spiral lens momenta are protected from dirt and

FIG. 4. The Vinten camera.

are designed to resist wear, while the lens is not revolved in focusing. The sleeve for connection to the drive motor contains a "mechanical fuse," which slips and makes a warning note in case the film jams.[18]

The Super Parvo camera (*Debrie*), made in France, is equipped with inside magazines having a capacity of 300 meters of film. Lenses are mounted in the conventional Debrie manner permitting the use of lenses of all focal lengths. Focusing is done either directly through the film or on a ground glass that can be switched to occupy an exact position at the focal plane of the lens. The film mechanism

is equipped with stabilizing pins and an intermittent pressure plate. Care has been taken to make it silent in operation. The motor is contained in the camera case and it is possible to interchange the three types of motors recommended; namely, 220- or 110-volt synchronous, or a 24-volt d-c. motor. The lens is protected by a sheet of optical glass set precisely in front of it. The usual tachometer, footage, and picture counters are part of the camera.[19]

While various manufacturers of cameras have been busily engaged in developing a suitable silent camera for sound picture work, various studios have been active in improving old "blimps" and designing new ones to be used with the older cameras. One of the most successful of these "blimps" is that now being used by Paramount at the studio in Hollywood. The new Bell & Howell rotambulator[20] is a camera stand consisting of a carriage mounted on three wheels and a columnar camera platform upright. The camera can be raised from 18 inches from the ground to a 7-foot height while operating or not. Both pam and tilt are controlled in operation through oil viscosity insuring smoothness of operation. Pamming is controlled by foot action and tilting by a conveniently placed hand lever.[20]

The last report mentioned two new types of "zoom" lenses for motion picture work, which were marketed for the first time in 1931. It was stated at that time that no account was available of the results that were obtained with such adjustable focus objectives. Three papers on the subject have appeared since then,[21] and the one published in the JOURNAL last October by Warmisham and Mitchell gives a good summary of the uses to which the zoom lens can be applied. The essential feature of all such equipment is that it be mechanically rigid, and so made that the focal length can be changed without disturbing the location of the precisely focused image on the film.

A new so-called "zoom" lens is announced by O. Durholz, described as giving smooth variations of $4x$, or for 40- to 160-mm. focal length, and as being focused without auxiliary lenses. The lens weighs 5 pounds, and fits on the standard camera turret mount without interfering with other lenses. The iris diaphragm is automatically adjusted to maintain the effective aperture, which is $f/8$ at full range and $f/5.6$ at $3\ x$ magnification.[22]

Little else can be said concerning new photographic objectives except to note the usual number of patents on new constructions.[23] The field of camera view finders has been definitely extended during

the past year by the application of new optical systems: there are at least two finders now on the market that image the whole field of a 25-mm. lens on a standard aperture. One of these is made by Harrison & Harrison,[24] the other by the Mitchell Camera Company. A third, made by Beck in England and called the "Focostat," is adjustable for all focal lengths of objectives from $1^3/_8$ to 8 inches.[25]

There is no new evidence that practical use is being made of cylindrical lens systems in an effort to expand the screen picture in the horizontal direction. There is still considerable interest in these so-called anamorphosing systems, however, as the literature of the past year shows. H. W. Lee has published an analysis of cylindrical optical systems with particular reference to their application in sound recording units.[26] The perspective and distortion of cylindrical elements has been discussed by Dr. G. Kögel,[27] while Henry Dain has written a lengthy account of the performance of Professor Chrétien's anamorphotic objectives,[28] concluding with an argument for their use to get a wider screen image from standard film. From Dr. J. S. Watson, Jr., has come a different contribution to the subject, in which he explains the theory of the cylindrical Galilean telescope and its use in the production of special photographic effects.[29]

3. *Studio Illumination.*—There is little to report in the way of progress in studio illumination in the United States. The General Electric Company, Ltd., of London, advise that they have recently introduced a new type of adjustable cradle for 2.3- and 5-kw. studio projectors as shown in Fig. 5. In this cradle the back strut is adjustable so that the projector may be set at any desired angle. The same company announces a portable photographic reflector which employs a special 500-watt Osram photographic lamp. This lamp has a small internally frosted pump and operates at a high efficiency, producing an even light.

The General Electric Company also announces a new 2-kw. spotlight which is only 12 inches in diameter and is fitted with an optically worked parabolic mirror. It is said to be particularly useful where there is not sufficient space to accommodate a larger spotlight. A 2-kw. Osram lamp having a flat filament is employed.

A British patent[30] has been issued to Claude Neon Lights, Inc., on a process of producing white light for photography with panchromatic and orthochromatic films, the red rays from an electric discharge lamp containing neon being blended with blue rays from a

discharge lamp containing mercury with or without neon or argon. The blue rays are passed through a yellow or amber screen. It is claimed that colors are not distorted, green being photographed as a lighter gray than blue.

4. *Exposure Meters.*—A new exposure meter, manufactured by the Weston Electrical Instrument Corp. of Newark, New Jersey, makes use of the photronic photoelectric cell which converts light energy directly into electrical energy without requiring any batteries to furnish any additional power. Two of these cells are mounted in

*Courtesy of General Electric Co., Ltd.*

FIG. 5. Illustrating adjustable cradle for studio projector.

the back of the instrument with covers that limit the angle included by them to 60 degrees. The brightness of the scene that is to be photographed is indicated directly on the scale of an instrument, and these readings are translated into proper aperture and timing by use of a cleverly designed calculator.

The calculator is arranged so that the basic film or plate speed may be taken into account by an initial adjustment made at the time the film is placed in the camera. The scene classification and the range of film sensitivity are based upon the fundamental response of film

emulsions and are very useful to the photographer in analyzing his scene and for obtaining the kind of negatives that he desires.[31]

5. *Color.*—Color cinematography has made rapid strides, despite the curtailment of budgets on developmental work of all kinds except those of exceptional promise of early liquidation. The applications have been sporadic due principally to the stringent demands of economy that have militated against all matters involving cost. There continues to be a demand for color particularly in the field of short subjects and cartoons, and the advance in quality of photography, definition, and color rendition, as evidenced by the several subjects that have come to the screen, is very gratifying.

Two full-length features and several short subjects in Technicolor were released during the year. These included four *Silly Symphony* cartoons in Technicolor's new process which have met with widespread approval and public demand. Greater realism was given the characters by using one drawing per frame instead of the usual one-to-four ratio.[32]

Cinecolor has announced a three-color process, which is described as follows: prints are made on double-sided film, exactly as the two-color prints are made; that is, with a basic dye color on one side and a blue iron tone on the opposite side. The red dye used for three-color work is of a magenta shade. To this double-sided film is added, by imbibition, a yellow dye image, resulting in a three-color effect. The camera has a beam splitter as used with two separate films. One gate feeds down one film while a bi-pack is fed through the opposite gate, producing three independent negatives. A matrix transfer plate is made from the blue negative, and the transfer is made in yellow to the double-sided film having the two-toned color images.

The Spicer-Dufay process which was described in the report for October, 1931, has recently been placed on a commercial basis. A regular color line screen is used on the film base, with a panchromatic emulsion over the screen. Exposure is made through the support. It is stated that the manufacturers intended to supply 9.5-mm. and 16-mm. widths as well as the professional standard 35-mm. width.[33]

Three patents on methods of making bi-pack negative films were published during the year.[34] Anderson has covered a process in which is used a double-coated negative having an orthochromatic emulsion on one side over a filter layer and a panchromatic emulsion

on the opposite side of the support. After development and bleaching, the original orthochromatic side is dyed red, and the opposite side is rolled with a fatty ink. The negative is then exposed through the red dye on a suitable printing material and the fatty ink is transferred by pressure.[35]

Capstaff has described the preparation of a color image which in its final form consists of a dyed gelatin relief image on top of an image in an insoluble colloid layer.[36] He also discloses a method of producing a colored picture image and a neutral toned sound record on the same film.[37]

Two patents are of interest which deal with methods of obtaining two-color subtractive prints.[38] Two differently sensitized emulsion layers are coated on a support. After exposure and development, the images are bleached, mordanted, and dyed with a single dye. The upper layer is then decolorized and converted to a complementary color to the lower dye image The second patent describes a method of successively coating and dyeing two layers on a single support.

Lawshe[39] uses a double-coated film for printing two components of a set of three-color record negatives, the third being printed on a separate film which is cemented to the first film after the color positives have been dyed in their appropriate colors. Three patents were noted that dealt with means of obtaining color records using the imbibition principle.[40] Bleach-out layers are featured in several patents on subtractive processes.[41] Thornton and Baker have each disclosed methods for producing a color screen in connection with additive processes of color cinematography.[42]

Inventive thought relating to lenticulated film processes has been very active in recent years as evidenced by the comparatively large number of patents issued. Methods of making embossing cylinders,[43] elimination of halation,[44] preparation of filters,[45] printing sound records on embossed films,[46] and projection of copies[47] are described. Eight disclosures were noted dealing with methods of printing embossed films.[48]

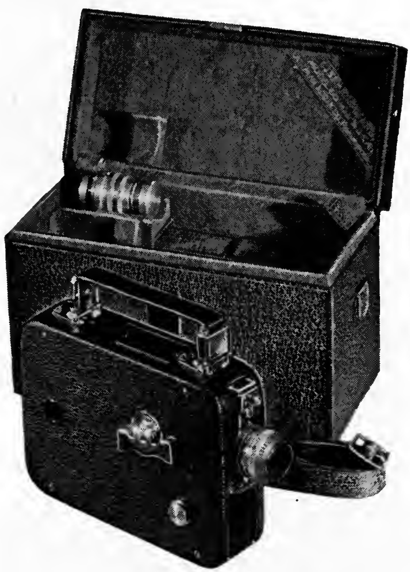
### *B. Amateur Cinematography*

1. *General.*—The past year has seen marked progress in the field of amateur cinematography, both in the improvement of existing apparatus and in the introduction of new materials and processes. The two most outstanding advances have been the 8-mm. film

introduced by the Eastman Kodak Co. and the Morgana color process introduced by the Bell & Howell Co.

2. *New Emulsions.*—A new non-halation super-speed panchromatic emulsion for 16-mm. work was announced in October of last year.[49] A low-priced reversal stock was made available in January, 1933, under the name Monofilm. Sufficient latitude for average lighting conditions and a speed about equal to that of orthochromatic film are claimed.[50]

The film used for the 8-mm. cameras described below carried a



*Courtesy of Eastman Kodak Co.*

FIG. 6. 8-Mm. camera.

different emulsion from that used on the already available 16-mm. amateur standard films. Inasmuch as the area of the 8-mm. frame is one-fourth that of the 16-mm. frame, and as a greater enlargement is encountered in projection, it was necessary to provide a very fine grain emulsion for use in these cameras. This film has a color-sensitivity comparable with that of the supersensitive film, but because of the fine grain and resulting decrease in emulsion speed, an exposure at $f/8$ is required for open scenes in bright sunlight.

3. *Cameras and Projectors.*—No radical changes in the design of

16-mm. cameras for amateur use have been made, although several types of professional cameras for film of this size have been introduced. Two of these have been described by Stull.[51] The Berndt camera was designed with sound-on-film recording in mind, although the camera described by Stull does not have this attachment. The other camera described, the Arri camera, which is of German manufacture, is a silent camera for 16-mm. professional work only.

The Eastman Kodak Co. has announced a complete line of cameras

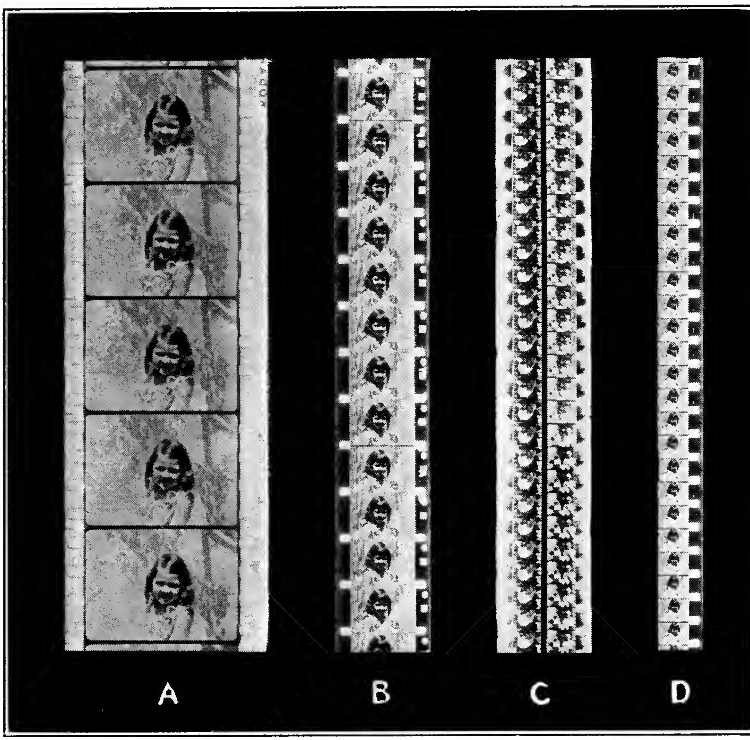
*Courtesy of Eastman Kodak Co.*

FIG. 7. Projector.

and projectors (Figs. 6 and 7) for a new size of substandard film, 8-mm.[52] This equipment, for black-and-white photography only, uses a film in the camera that is 16 mm. wide with half the perforation pitch of the present amateur standard film. During the run through the camera, only one side of the film is exposed, after which the roll is placed on the feed sprocket again; and on the second run through the camera the other side is exposed. After the reversal

development of the film, it is slit and cemented end to end. Thus a 25-foot original roll becomes 50 feet of 8-mm. film, which, because of its smaller perforation pitch, is equivalent in screen projection time to a 100-foot roll of the amateur standard film (Figs. 8 and 9).

Two models of cameras are available for this film, one carrying




*Courtesy of Eastman Kodak Co.*

FIG. 8. Comparison of several types of film. (a) Standard 35-mm. professional film; (b) standard 16-mm. amateur film; (c) standard 16-mm. amateur film containing four 4 × 5 mm. pictures per frame before cutting; (d) standard 8-mm. amateur film.

a fixed focus unremovable $f/3.5$ lens and the other a bayonet type mount $f/1.9$ lens which may be replaced by longer focal length lenses for telephoto work. Three types of projectors are listed. The largest uses a 20-volt 100-watt lamp to project a screen image 40 inches wide. The other two models differ only in the illumination source used. That for use on a 30-inch screen is equipped with a

100-volt 100-watt lamp, while the smallest projector uses a 32-cp. lamp for a 22-inch screen image.

The Weston Electrical Instrument Corp. has announced an exposure meter similar to the one described previously but intended primarily for amateur use. It is a simple instrument (Fig. 10) consisting of a photronic photoelectric cell on the back of an instrument movement. This cell is arranged with covers so that the angle included is 60 degrees. The instrument is calibrated directly in *f* stops for ordinary ciné panchromatic film at a speed of 16 frames per second. Conversion tables are supplied for converting these readings into proper exposure if different film is used or if a camera is used that has a different frame per second speed.

*Courtesy of Eastman Kodak Co.*

FIG. 9. Reels of film of equal playing time.

Another exposure meter known as the Skinner Meter[53] employing a single photocell has also been placed on the market.

4. *Color* (*16-Mm.*).—The Bell & Howell Co. has announced cameras and projectors for Morgana color, a two-color additive process wherein the flicker usually associated with this type of process has apparently been overcome by a very ingenious device.[54] The camera has an oscillating arm between the lens and the film into which the two-color filters are inserted. This shuttle carries the filters back and forth before the film so that alternate frames are exposed respectively to the two colors. The lens is opened one full stop more than that required for black-and-white photography under the same lighting conditions, and the camera is operated at a speed of 24 frames per second.

After the film has been processed by the usual reversal method it is projected on a special projector for this type of film. The film movement mechanism advances the film 2 frames, backs it up 1 frame, advances it 2 frames, *etc.* A wheel carrying the appropriate projection filters is rotated before the lens in synchronism with the film movement. Due to the special movement, the frames are alternated on the screen at the rate of 72 pictures per second, although the net rate of travel of the film is the same as in the camera; namely, 24 pictures per second. As a result of the fact that each frame is projected 3 times, and because of the high frequency of the alternation of frames on the screen, there is no apparent flicker.


*Courtesy of Weston Electrical Instrument Corp.*
FIG. 10. Exposure meter for amateur use.

Although this is a two-color process, subject to the limitations in color rendering common to such processes, and although rapidly moving objects do produce a fringe, the process presents many advantages for the 16-mm. field. It has been described completely by J. A. Dubray at the 1933 Spring Meeting of the Society at New York, N. Y.

Films made by a lenticular color process known as Agfacolor were shown at the annual exhibition of the Royal Photographic Society in September, 1932. The film support is covered vertically with cylindrical embossings, 36 to the millimeter. Tri-color banded filters are used before the $f/1.5$ or $f/1.9$ lens on the camera, and in the lens system of the projector.[55]

In the field of projection equipment for 16-mm. film, the trend toward greater screen illumination that had previously been noted has continued. The Victor projectors have had the optical system improved,[56] while the Bell & Howell Co. now provides a 400-watt lamp in the type *JL* projector.

Two new printers for 16-mm. film have been announced. The Arri printer is a step printer[57] while the Wood-Watson[58] is a continuous printer for sound film.

## II. SOUND RECORDING

1. *General.*—The necessity of reducing costs of all sorts in the studios during the past year has militated against the introduction of new sound recording equipment on any extensive scale. However, the producers of electrical sound systems have been active in introducing improvements in the older systems and in some cases complete new recording outfits.

2. *New Recording Equipment.*—In the last report of the Committee brief mention was made of a new portable Western Electric recording system. This system, which has recently been described[59] in detail, has been in successful operation in several of the major studios during the past year, and one of the units was taken to Greenland with the Universal-Dr. Frank expedition for making the new Arctic epic, *S.O.S. Iceberg.*

The Western Electric Co. has announced a simplified recording amplifier system known as the type *P* system. This new system consists essentially of one or more moving coil microphones located on the stage, each of which is connected to a single-stage transmitter amplifier located in the monitor room. These amplifiers are then terminated by a mixer panel which in turn is connected to one or more single-stage booster amplifiers in tandem as required to deliver sufficient level to operate the final power amplifiers. The booster amplifier and the mixer panel are also located in the monitor room. The small current consumption of the transmitter and booster amplifiers makes it possible to use small automobile storage batteries for the filament supply and dry *B* batteries for the plate voltage. Due to the small space required for these batteries, they can be readily located in the monitor booth. The power amplifiers that terminate the booster amplifier are located in the recording room adjacent to their respective recording machines. These amplifiers

consist of a single stage of push-pull amplification and are all operated by alternating current.

On comparing this system with the old amplifier system, it will be noted that the large expensive *A* and *B* storage batteries, the battery charging motor generators and the power board have been eliminated. The room formerly occupied by these batteries, the amplifier room, and the floor space for the battery charging motor-generators and power board are no longer required. This arrangement admits of a considerable saving in wiring and installation expense. All these improvements have been obtained without interfering with the flexibility of the recording system.

The RCA Victor Co. has introduced a new recording and reproducing equipment designated as "high fidelity." The new recording equipment is claimed to be capable of recording a range of frequency up to approximately 10,000 cycles. Some of the other improvements consist of a permanent magnet velocity microphone; a mixing panel in which operation noises have been reduced to a minimum; a new recording amplifier, electrically superior to previous types, ruggedly constructed so as to withstand hard usage; a new system of reducing ground noise, from which are omitted the external shutters used heretofore with variable width sound tracks. The new system utilizes a biased galvanometer method of controlling the width of the transparent portion of the sound track.

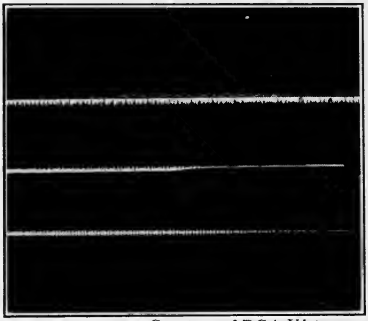
The recorder is mechanically superior to previous models, which results in extreme quietness of operation. A new optical system of extreme simplicity and ruggedness is utilized employing a galvanometer of the dry type and a much larger mirror than those used heretofore. This results in less stray light, and assists in making the refinements required to record the higher frequencies accurately.

Electrical equalization for film and slit losses is provided in the form of a separate panel incorporated in the standard recording channel. This equalization results in a constant output from the photocell of the reproducing equipment when prints of the sound record are reproduced. The variable width symmetrical sound track employed in the "High Fidelity" recording system is claimed to have many advantages over the single-edged track previously employed, among them being the attainment of a greater degree of noise reduction. Fig. 11 illustrates the forms of single- and double-edged tracks.

A new recording system is reported from Great Britain, the main

feature of which is that the recording can be accomplished without any electrical amplification whatever. The essential principle of the invention is embodied in a circular panel of glass about two to three inches in diameter, lined with a grid of mirror bands. A lamp throws a beam of light through the strips of glass between the mirror bands, which is focused down and received as a series of minute points of light upon a small mirror oscillator.

This mirror oscillator may be controlled either by the usual microphone and amplifier, or by direct speech. Its effect is to redirect the light received through the apertures between the mirror strips on the glass tube back to the mirror strips. As the oscillator works, more or less of the light impinges on to the mirror strips. The light so received is reflected into the apparatus and focused



*Courtesy of RCA Victor Co., Inc.*

FIG. 11. Single- and double-edged variable width track.

on the film through the usual mil slits. The magnification depends upon the number of mirror points employed in the grid.

This system, therefore, constitutes a recording apparatus consisting simply of an optical system without any necessary electrical amplifying device, as the amplifiers can be omitted because of the almost unlimited degree of optical magnification. It is claimed that this apparatus can be used for either the variable width or variable density methods of recording.

While wax recording for motion picture purposes has greatly declined in favor of film recording methods, the spectacular success of the new vertically cut records made by the Bell Telephone Laboratories is again focusing attention on this type of recording. These

records possess important advantages over laterally cut records.[60] The electrical recorder and the reproducer used in the system have also been greatly improved. "Cathode sputtering" has replaced the old method of graphiting the wax, and a non-abrasive record of cellulose acetate has replaced the abrasive record of the past. These improvements have reduced the surface noises to the extent of 25 to 30 db., and have increased the life of the record tremendously. The volume range has been increased from about 25 or 30 db. to about 50 or 60 db., and the high-frequency cut-off has been extended nearly an octave (to about 9000 cycles). A more faithful reproduction has been obtained as a result of a flatter frequency characteristic and less non-linear distortion, so that sounds are more distinct, lifelike, and clean-cut.

3. *New Recording Methods.*—One of the most important developments from the standpoint of economy of operation originated in the Hollywood studios during the past year. This was the introduction, first by Metro-Goldwyn-Mayer, of recording two sound tracks on a 35-mm. film, thus reducing the sound negative footage by 50 per cent. Prints were then made which also carried two sound tracks. This print was slit down the middle, producing two 17.5-mm. films, which were then assembled for the "dailies" and run through the projection machines in synchronism with the action. For final cutting of the negative sound track it was, of course, necessary to split the sound negative and treat each 17.5-mm. film as a single negative film.

This method has been adopted in varying degrees by many other studios. Some continue to record only one sound track on the negative, but make 17.5-mm. prints from this negative. Others split the 35-mm. film before recording, and record directly on the 17.5-mm. film, using only one set of sprocket holes in pulling the film. This requires a modification of the film recorders and developing machines to handle the narrow film, whereas the original method used by MGM does not require changes in recorders or developing machines. Both systems require slight modifications of the projectors in order to accommodate the 17.5-mm. film. The narrow film affects the theater only in cases of double film previews in which the separate sound track is made on 17.5-mm. film.

Another method of saving raw stock without splitting the film is to break down the negative before development and to develop only approved takes, these being denoted by suitable punch marks. The remaining raw stock is patched together and the opposite

unused edge is used for printing the daily sound track. It is difficult to make an offhand comparison as to the relative economies effected, since the entire production technic is involved.

4. *Microphones.*—The tendency is away from condenser microphones and their associated amplifiers toward dynamic permanent magnet microphones. The lapel microphone also looms as a possibility in certain kinds of recording, although its use to date has been limited to public address systems.[61]

The ribbon microphone is a velocity operated pick-up device, in contrast to other microphones which are pressure operated.[62] It is claimed that its directional properties offer the following operating advantages: (1) the elimination of undesired interfering noises; (2) the reduction of recorded reverberation; (3) bi-lateral sound pick-up; (4) regulation of the extent of the sound pick-up by adjusting the angle of the source of sound with respect to the microphone as well as the distance of the source from the microphone; (5) the elimination of acoustic feedback in public address systems, or from monitoring loud speakers by suitable angular-positioning of the microphones with respect to the loud speakers; (6) the elimination of reflection difficulties in acoustical measurements.

Equipment for handling microphones has been improved but slightly during the past year. The durable Mole-Richardson booms continued to be widely used, and there were no outstanding improvements in the smaller portable booms of the "dolly" type. One studio has developed a smaller lighter boom similar in principle to the Mole-Richardson boom, but designed to carry microphones of the dynamic or ribbon type, which do not require closely associated amplifiers. The use of "concentrators" of the reflector type has increased, and some models which have been adjusted mechanically or equalized electrically, are said to provide recordings that are not readily distinguishable from those made with a standard microphone. The reflectors vary in size from three to six feet in diameter, and are installed in light hand-trucks in universal mountings. Concentrators are not often used on the stages because of undesired reverberation effects. With reference to microphone placement, there has been no material change in practices. In general, perspective is controlled by adjusting the average distance of the microphone from the artist in order to obtain the desired effect.

5. *Motor Systems.*—In attempting to eliminate noisy gear systems from camera motor assemblies, the MGM studio has experimented

with a direct connection of the shutter shaft of the camera to the motor armature. In order to permit a direct connection of the armature and shutter shaft, the motor speed must be 1440 rpm. A four-pole three-phase synchronous motor, such as is generally available, would therefore require a 48-cycle power supply, in the form of suitable frequency-changing equipment operated by the standard 50- or 60-cycle source of power. This has been accomplished experimentally in the MGM studios, using a 5 kw. 48-cycle machine.

In order to assure synchronism with standard recording machines having a drive-shaft speed of 1200 rpm., a six-pole 60-cycle 3-phase synchronous motor can be used.

With a complete 3-phase synchronous motor system, such as described, equipped with suitable starting reactors, phase correctors and slip clutches in order to assure smooth starting, it is necessary to provide a new system of synchronizing marks and scene identifications. At MGM an experimental system is based on a single master control that starts all motors, illuminates the film in the recorder, exposes a synchronizing mark on all sound and picture films, and operates a "speed" signal. All this is accomplished during a four-second interval. An additional synchronizing mark is automatically placed at the end of each take. In conjunction with this system, both edges of the recording stock are used for the sound record, takes are identified by edge numbers on the film, and camera slates are used only on the first scene of each roll of picture negative. Title slates are made up independently, and are inserted when the developed film is assembled into the "daily."

6. *Accessories*.—The development of accessory apparatus and technics for control and test purposes in sound recording has continued throughout the year. A new type of mixer control for dynamic microphones has been developed by the General Radio Co.,[63] which is claimed to be noiseless in operation and to provide linear attenuation up to 45 db. with logarithmic cut-off.

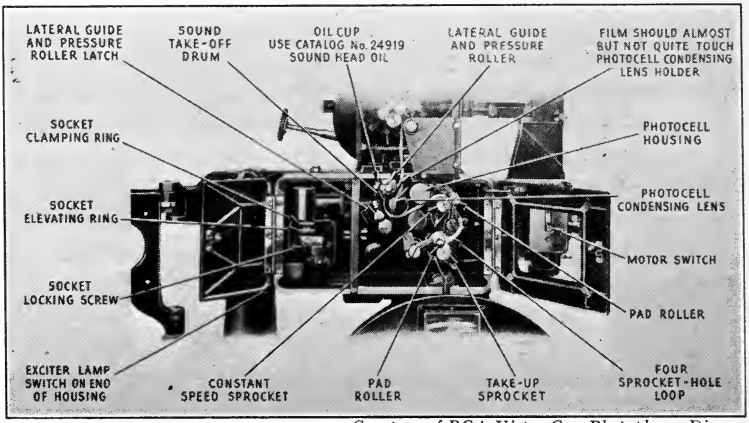
A simple rapid method of directly measuring the distortion in audio-frequency amplifier systems has been described by Tuttle.[64]

### III. SOUND AND PICTURE REPRODUCTION

1. *New Sound Equipment*.—Considerable progress has been made during the past year in sound reproduction. The two major suppliers of electrical equipment have announced systems that tend to im-

prove the overall quality of sound reproduction from film, the specific improvements being an extension of the frequency range to lower and higher frequencies than those previously reproduced, and an improvement in the motion of the film past the scanning aperture in the sound head.

The RCA Victor Co. has announced and installed in several hundred theaters reproducing equipment capable of reproducing sound at frequencies up to 9500 cycles. This equipment is extremely simple and is operated entirely on alternating current. The sound heads are of the drum type. There is no film gate, and no sliding contact between the film and any parts in the sound head. This feature is said to assure freedom from troubles during reproduction




*Courtesy of RCA Victor Co., Photophone Div.*

FIG. 12. Rotary stabilizer sound head.

due to wax and emulsion, and sprocket hole flutter, and to provide the uniform motion of the film past the scanning light beam required for satisfactory reproduction of the higher frequencies.

A photograph of the "rotary stabilizer" sound head for standard series RCA Victor Photophone high fidelity reproducing equipment is shown in Fig. 12. Four of these sound reproducing units are used in the projection room of the RKO Roxy Theater, in New York, N. Y.

Electrical Research Products, Inc., has announced a "wide range" sound system. According to a report from this company the term "wide range," as applied to the Western Electric sound system, denotes a widened or increased frequency spectrum, and sometimes

an increased volume range. In terms of equipment, various apparatus components are added to the system, or existing elements are replaced; although with few exceptions this treatment does not involve what may be considered major apparatus developments.

The new *596* loud speaking telephone (Bostwick receiver), which has been described elsewhere at some length in technical papers, and the *TA-4151* loud speaking telephone, are additions to the loud speaker equipment already installed where a wide range conversion is to be made. These instruments have already acquired the significant popular names of "tweeter" and "woofer," respectively. The new curved reproducer gate (*TA-7260* aperture), which will be described separately, represents development by ERPI that was necessary before satisfactory wide range reproduction could be offered from sound film. The other material used embraces equalizers, coupling networks for dividing the loud speaker circuits, heavy baffles for mounting the "woofers," and various auxiliary equipment, such as power relays and the like.

It is perhaps noteworthy, as regards the application of wide range conversion equipment to all Western Electric sound reproducing systems now in use, that special attention has been given to obtaining an over-all standard result among the various types without involving the licensee in the expense of junking his equipment wholesale or replacing apparatus that is in good order. Customers have the option of modernizing their installations, however, as in such cases, for example, where early types of sound reproducers and storage batteries are in use; if desired these will be replaced at nominal charges with reproducer and power unit equipment of the latest types. This latter treatment, where it applies, so reduces current maintenance costs that the idea is very attractive and proving popular.

The new aperture referred to above consists of a cast frame supporting a lens tube assembly, a curved film-supporting surface to guide the film past the scanning lamp beam, and a freely running flanged guide roller to maintain the film in lateral alignment. A sliding frame opened and released by a self-locking cam on the main frame supports two film shoes that hold the film against the guide roller and the sound sprocket, respectively.

All frictional contact with the film, both at the curved gate and at the two pressure shoes, is on the base side, leaving the emulsion side of the film open. Consequently, there is little opportunity for accumulations of emulsion to form.

While easier to thread and simpler to maintain than apertures of the older type, the greatest advantage of the new design is the reduction in 96-cycle flutter that modulates the higher frequencies and causes a quality of reproduction commonly described as "fuzziness."

The recent introduction of wide range makes this new aperture particularly timely, since the broadening of the frequency band at the two ends of the spectrum imposes more severe requirements on the reproducing equipment, especially as regards the prevention of flutter. The new unit has consequently been made standard for all wide range installations.

2. *New Projectors and Accessories.*—In addition to the changes in reproducing equipment that benefit sound reproduction, improvements have been made in the general operation of projection equipment. For example, the International Projector Corp. introduced the Simplex-Acme change-over device in 1932. By means of this device, which is attached to the douser control of the Simplex-Acme projector, and by the pressure of a switch on either projector, the douser of the incoming projector is opened and that of the outgoing projector is closed. At the same instant, however, the sound is changed from the outgoing projector to the incoming projector by an electromechanically controlled device attached to the amplifier switch. The change-over is claimed to be made without electrical disturbance in the sound system and, of course, is instantaneous.

Projection objectives have been changed very little during the year. The Dallmeyer firm has announced a new lens series called the *Superlite*, having a speed of $f/1.9$ for which a 33 per cent increase in illumination is claimed.[65] An analysis by W. B. Rayton[66] of the optical systems used in short-focus lenses for projectors behind the screen has appeared in the JOURNAL. One new objective of this type has been patented.[67] R. F. Mitchell has contributed an interesting article on keystone distortion as produced by projectors at varying angles from the normal to the theater screen;[68] from the diagrams that illustrate the article the cameraman can determine to what extent his work will appear distorted when shown in the theater.

Non-intermittent projectors are still being discussed,[69] it appears, without arousing much active interest except among examiners in the Patent Office.[70] The same is true for stereoscopic apparatus,[71] and in this case the list of patents is a large one.[72] For the benefit of those who did not hear Dr. Ives' thorough exposition of the subject

of stereoscopic projection at the October, 1931, meeting of the Society, his paper has appeared in the JOURNAL.[73]

3. *16-Mm. Sound-on-Film.*—A certain amount of progress has been reported in the recording and reproduction of sound on 16-mm. film during 1932. Although no discoveries or inventions have been reported that tend to modify or obviate the limitations imposed by the slow linear motion of the film, an agreement by several manufacturers of amateur equipment on certain standards should result in a wider use of this medium.

Under this agreement, it has been decided to retain the 16-mm. width but to dispense with one row of perforations. The size of the picture will remain unchanged. The sound track will be 0.065 inch wide with its central line midway between the edge of the film and the side of the frame. A standard projection speed of 24 frames per second has been agreed upon, and the lead of the sound gate has been set at 25 frames. Standards embodying the details given above have been adopted and published by the Society.[74]

The RCA Victor Co. has announced a new 16-mm. sound-on-film projector utilizing a 400-watt projector lamp, a number of which machines are in commercial use for advertising and educational purposes. A number of large national advertisers have utilized 16-mm. sound motion pictures for personnel and consumer education on their products.

An important step toward the development of the non-theatrical sound motion picture field was made by the RCA Victor Co. in establishing a 16-mm. sound-on-film library. The film subjects in this library are classified as Detective Stories, Aviation, Animated Cartoons, Sports, Travelogues, Comedies, Music Appreciation, *etc.* Burton Holmes Lectures, Inc., foremost producer of the travelogue type of screen subject, is producing additional subjects for the 16-mm. sound-on-film field from a large library of available negatives.

## IV. FILM LABORATORY PRACTICE

1. *Film Development.*—An improved process of developing film and the apparatus required for it have been developed by the Roy Davidge Film Laboratory, in Hollywood. The developing tank is semi-cylindrical, its axis being horizontal. Two wheels serve as reels on which the film is wound, the wheels being mounted on a con-

centric false drum coaxial with them. This false drum is removed after the film is mounted on the reel, causing the upper layers of the film to press together. One of the novel features of the method is the use of a celluloid spacing strip between adjacent layers of film, which is embossed in such a manner that dome-shaped protuberances project from each of its surfaces. It is claimed that these protuberances break up the flow paths of the developer, resulting in a film free of streaks, chemical and directional effects, and underdeveloped areas.

2. *Printers.*—The new Bell & Howell automatic printer,[75] described in last year's report, has undergone extensive tests at the MGM laboratory. The optical system has been improved, increasing the illumination and thereby allowing the printing aperture to be still further reduced. This in turn increases the definition of both the picture and the sound track on the prints. A special rheostatic control has been inserted in the lamp circuit consisting of two parts, one allowing a coarse adjustment in 2-volt steps, the other a final adjustment in 0.2-volt steps.

The Horsley Laboratory of Hollywood has devised an attachment for the standard type *D* Bell & Howell printer which reduces the time and labor involved in making composite prints. The sound track is printed simultaneously with the picture, using a supplementary drum situated between the main gate and the lower take-up reels. The negative may be used either "head first" or "feet first." A rerecorded sound negative having constant transmission throughout is required as only one printing light is available.

A new rotary printer has been developed by a British firm[76] which is claimed to have unusually high printing accuracy, and consists of a unit that is completely independent of both mechanical and electrical considerations. Both the light changes and lamps are operated by power generated by the driving motor which runs at constant speed on alternating current mains. Due to the unvarying current supply and the constant speed of the machine, the film densities remain constant over the entire working day.

A perfect contact between the two films is achieved by the curvature of the gate on the top of the light box, and tension is supplied to the positive film only. Uniform transmission of the film is attained by means of a patented mechanical filter that drives the precision sprocket, the latter having an involute tooth cut to a special depth to take two films.

Rewinding the negative is avoided by using a forward and reverse chart control band. No stapling, notching, or other damage of the negative is necessary with this light control system, although the printer can work with negatives so treated. The densities are recorded on a parchment chart 70 mm. wide, which is placed in the printer at the start and is automatically synchronized by the machine. The composite machine, when locked together by the gear-box, produces picture and track at one run of the negatives at a speed of 100 feet per minute.

A new process in studio "dissolve" work is claimed by a British laboratory.[77] This is accomplished efficiently and inexpensively by making a duplicate negative by an optical method from the two original negatives that have been dissolved into one another. The new negative exactly matches the originals, but contains the dissolve made exactly in the right place, so that there is no loss of synchronism when it is subsequently wedded to the sound track. The dissolve is perfectly smooth and entirely free from the flicker often found in chemical dissolves.

3. *Editing.*—A new film cutting and editing machine, capable of handling either single or double film has been developed and produced by the Western Electric Co., Ltd.[78] (Fig. 13.) The machine, which will furnish high-quality reproduction either by head telephones or loud speaker, incorporates a novel viewing mechanism that passes the film through the picture gate at constant speed. The stationary picture is obtained by means of rapid flashes of light from a neon lamp located below the picture gate, which occur in synchronism with each picture frame as it passes the view finder.

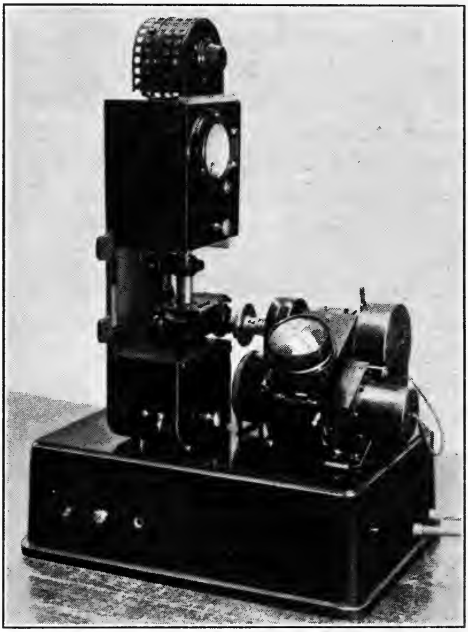
## V. APPLICATIONS OF MOTION PICTURES

1. *Education.*—The use of talking motion pictures for educational purposes has been discussed widely for several years, but it remained for the University of Chicago, under the able leadership of President R. M. Hutchins, coöperating with E. R. P. I. Motion Picture Consultants, Inc., to initiate the production of educational pictures to be used as an integral part of the general courses for freshmen and sophomores.

During 1932, two films of the physical science series were made, covering the subjects of oxidation and reduction, and the molecular

theory of matter. In these films the off-stage method of explanation is used throughout. It is planned to produce 20 films in the physical science series and a similar number in the biological and social sciences and in the humanities.

The use of motion pictures in astronomical work continues unabated. A description of a motion picture of the moon made at the Treptow Observatory is published in *Filmtechnik*. Single frame exposures, each lasting from $^1/_4$ to $^1/_2$ second, were made at intervals



*Courtesy of Western Electric Co., Ltd.*

FIG. 13. Cutting and editing machine.

of 5 seconds, giving for the duration of the $3^1/_2$- hour eclipse a projection time of $1^1/_2$ minutes at 24 frames per second.

The introduction of sound equipment in schools during 1932 was retarded considerably by current economic conditions. Some of the more progressive schools managed to install sound equipment, one of the outstanding installations being that made at the Samuel Gompers Industrial High School in New York City.[79]

2. *Race Timing Devices.*—Apart from the progress made in the

use of motion pictures in educational and medical fields, the most outstanding application of general interest in 1932 was the use of this medium in connection with the timing of track events at the Olympic Games in Los Angeles.[80] A 16-mm. Bell & Howell camera was arranged so that it photographed simultaneously, at 128 frames per second, the finish of the race and the dials of a clock driven by a synchronous motor at a speed of 10 rpm., the motor in turn being driven by a 200-cycle tuning fork generator. The clock face consists of three rotating dials, the inner dial rotating at one revolution per second, and having one hundred divisions. The middle dial, having 60 divisions, rotates at one revolution per minute; and the outer dial, also having 60 divisions, rotates at one revolution per hour; thus making it possible to read minutes, seconds, and one-hundreths of a second. The clock is automatically started, from a pre-set zero position, with the closing of a switch built into the starter's pistol and closed when the trigger is pulled.

Along this same line the Bell & Howell Co. has announced a micro-motion camera consisting of a "Filmo" camera mounted in conjunction with an optical system that permits photographing a chronometer at the same time as the action for time-study cinematography. A lamp house is an integral part of the optical system, and illuminates the chronometer and a title card, the images of which are reflected in the field of a 1- or 2-inch photographic lens. A focusing device permits maintaining the sharpness of the images of the chronometer and title for any distance of the object being photographed.

The U. S. Navy continued during 1932 the active use of motion pictures in the general scheme of the Naval organization, touching on its entertaining, instructional, and recruiting value. For entertainment alone the Navy owns, in duplicate, 467 features, and is acquiring monthly an average of 25 features and 5 short subjects.

The Academy of Motion Picture Arts and Sciences has participated actively with the War Department in mapping out a course of study of the production of talking motion pictures. The Signal Corps of the U. S. Army has assigned Capt. M. E. Gillette to Hollywood for six months to participate in this study.

Among the activities of the Academy of interest to the Society are the formation of committees studying the establishment of an effective uniform practice as regards the length of reels, the revision of standard release print make-up, methods of improving the average

quality of release prints, establishment of uniform screen illumination in studio reviewing rooms, investigation of film preservatives, and elimination of blimps through development of a silent camera.

### VI. PUBLICATIONS AND NEW BOOKS

A well-known exhibitor's publication, the *Bioscope* (London), was incorporated with *Kinematograph Weekly* (London) and the combined issue published in an enlarged format. The section of this publication devoted to the theater is now issued separately as the *Ideal Kinema and Studio.* Another journal was added to the growing list for the ciné amateur under the name *Home Movies* (London). A quarterly publication containing articles related to the use of motion pictures in biology was initiated during 1932. It is called *The Journal of the Biological Photographic Association* (Baltimore). A useful compilation of publications and books concerned with cinematography was published by G. E. Matthews.[81] A list of the principal books appearing since the last report of the committee follows:

1. *Year Book of Motion Pictures—1933,* 15th Edition, Film Daily, New York.
2. *Motion Picture Almanac—1932,* edited by Motion Picture Herald, Quigley Publishing Co., New York.
3. *Kinematograph Year Book—1933,* Kinematograph Publications, Ltd., London.
4. *General Annual of Cinematography—1932–1933* (*Annuaire Générale de la Cinématographic 1932–1933*), Ciné-Magazine, Paris.
5. *Yearbook of Photography, Cinematography, and Reproduction Processes for the Years 1928–29* (*Jahrbuch für Photographie, Kinematographie für die Jahre 1928–29*), Vol. 31, Pt. 1, edited by J. M. Eder, W. Knappe (Halle).
6. *Sensitization and Desensitization* (*Sensibilisierung und Desensibilisierung*). This is Vol. 3, Pt. 3, of *Ausführliches Handbuch der Photographie,* edited by J. M. Eder, W. Knappe (Halle).
7. *The Photographic Objective* (*Das Photographische Objectiv*); *The Theoretical Basis of the Photographic Process* (*Das Theoretischen Grundlagen der photographische Prozesse*); *Scientific Applications of Photography* (*Wissenschaftliche Anwendungen der Photographie*). These are Vols. I, V, and VI, Pt. 1, respectively, of *Handbuch der Wissenschaftlichen und Angewandten Photographie,* edited by A. Hay (9 vols.), J. Springer, Vienna.

8. *Cinematography and Talkies*, by J. R. Cameron and J. A. Dubray, Cameron Publishing Co., Woodmont, Conn.

9. *Introduction to Sound Photography* (*Einführung in die Tonphotographie*) by J. Eggert and Richard Schmidt, S. Hirzel, Leipzig.

10. *Fundamentals of Sound Films* (*Die Grundlagen des Tonfilms*), by F. Skaupy, Union Deutsche Verlags., Berlin.

11. *The Film in National Life*, edited by Sir Benj. Gott, Allen and Unwin, Ltd., London.

12. *The Amateur Ciné Movement*, by Marjorie A. L. Burgess, Sampson, Low, Marston & Co., Ltd., London.

13. *Motion Pictures and Lantern Slides for Elementary and Visual Education.* A compilation by H. E. Brown and J. Bird, Lincoln School Teachers College, New York.

14. *Making Better Movies*, by A. L. Gale and R. C. Holslag, Amateur Cinema League, New York.

15. *The Principles of Optics*, by A. C. Hardy and F. H. Perrin, McGraw-Hill Book Co., New York.

16. *Photocells and Their Application*, by V. K. Zworykin and E. D. Wilson, John Wiley & Sons, New York.

17. *Report of the VIII International Congress of Scientific and Applied Photography* (*Bericht über den VIII Internationalen Kongress für Wissenschaftliche und Angewandte Photographie*), Dresden, 1931, A. Barth, Leipzig.

18. *Acoustics and Architecture*, by P. E. Sabine, McGraw-Hill Book Co., New York.

19. *Advances in Physical and Technical Acoustics* (*Fortschritte der physikalischen und technischen Akustik*), by F. Trendelenburg, Akad. Verlags., Leipzig.

20. *Sound Film Reproduction* (*Tonfilmwiedergabe*), by R. Dahlgreen, Union Deutsche Verlags., Berlin.

## VII. APPENDIX

### *A. General Field of Progress of the Motion Picture Industry in Great Britain*

The year 1932 has been an uneventful one, for the need of retrenchment resulting from economic conditions has had its effect upon the industry. It has failed to produce any outstanding development in new equipment or technical accessories.

What progress has been made has been largely concerned with the refinement of technic in recording sound and in production methods

brought about by a growing realization of the need of higher standards than in the past.

Notwithstanding prolonged economic depression and high taxation, certain advances are taking place in the film industry in Great Britain. Developments not only in the construction and the operation of theaters, but also in the production and preparation of films, have been progressing along sane and economic lines. While there have been no drastic changes in screen technic, progress has been constant, so that in spite of a severely restricted foreign market for the films, the British industry stands in a favorable position.

An examination of the new theaters shows that, generally speaking, the average capacity lies approximately between 1500 and 2000 seats, although the latter figure has been exceeded in the case of the Gaumont Palace at Lewisham with its 3300 capacity, and the Gaumont Palace at Hammersmith with its 3600. Others completed during the year hold from 2500 to 3000, and one is now being built in London which will hold 4000. The theaters are being very much better planned, and allowance is being made in the majority of cases for expansion if the business continues to progress in the same ratio as in previous years.

It is probably in connection with the interior decoration of the cinema that the greatest progress has been made, and considerable attention is paid in designing the building to permit the use of absorbent materials in order to take care of the acoustic properties of the theater.

Probably one of the most outstanding occurrences of the year was the inauguration of the new Gaumont British Studios at Shepherds Bush, London, which provide extensive facilities for production work. Built on the site of the old 1914 building of the original Gaumont Company, the new studios were opened in July.

The available floor space of the new studio blocks is over 80,000 feet and, in addition, there is another block to house additional studios, executives, workshops, *etc.* There are five large studios, the largest of which is 85 feet wide and 136 feet long. Each is provided with the fullest service accommodation. The overhead lighting is suspended from trolleys on a system of runways, enabling lamps to be centered or banked as desired. Galleries at two heights facilitate the direction and placing of the lighting equipment. In addition to the space already mentioned, an adjoining building houses the film printing laboratory, which handles over 2,000,000 feet of film per week.

A total number of 153 British made films were shown to the trade in England during 1932, as compared with 139 during 1931. American features shown to the trade decreased from 490 to 449, and Continental films increased from 38 to 39. Of the total of 641 films shown, only two were silent.

The Ministry of Agriculture is using films for publicity and propaganda purposes in connection with the National Mark scheme of marketing, distributed by Daylight Talking Picture vans employing 16-mm. equipment. The War Department, the Air Force Department, and the Admiralty have continued to use training films, and further developments are anticipated. The General Post Office is developing a scheme of telephone advertising through films.

### *B. Progress in Motion Pictures in U. S. S. R.*

As a result of the recent reorganization of the Soviet film industry and the consequent extensive production plans, raw film requirements of the Soviet Union are estimated, under the second five-year plan, to be 1,240,000,000 feet of raw film annually for the coming five years, according to a report based on Soviet sources to the motion picture division of the U. S. Department of Commerce.

Production capacity of existing raw film factories does not exceed 75,000,000 meters annually, it was stated. A new factory is reported being built near Kazan, with an estimated yearly production of about 150,000,000 meters. This factory is scheduled to be completed in 1934. Another factory having a yearly production of 200,000,000 meters is to be built in the near future. This unit will specialize in the production of more rare and expensive types of raw film.

There are at present 14 film studios in Soviet Russia, located at or in the vicinity of Moscow, Leningrad, Odessa, Kiev, Yalta, Tashkent, Aschkhabad, Stalinabad, Tiflis, Baku, and Erivan. Five factories manufacture apparatus for the production of sound and silent films.

At present there are about 1245 regular picture houses located in cities, having a total seating capacity of 535,000, or about 70 inhabitants per seat. Under the five-year plan it is proposed to increase the total capacity to 1,200,000 by 1937, or to about 40 inhabitants per seat. The plan further provides for the creation of 42,500 traveling cinemas for villages, with shows to be organized once every 10 days in villages of 100 to 200 inhabitants, and twice in 10 days in villages with 1000 to 2000 inhabitants.

It is proposed to produce talking pictures in the languages of the 47 different nations and tribes of Soviet Russia, Ukrainians, Tartars, Georgians, Kalmucks, and others, by "dubbing" Russian sound films.

*Sound in Soviet Russia.*—There are two major Russian sound systems which are entirely Russian in origin and manufacture, the Shorin and the Taguer. The outstanding characteristic of the Shorin recording camera is that it may be used to produce a variable width or variable density sound track. The recording unit is a single string galvanometer, normally used with the ribbon parallel to the sound track, and thereby producing a variable width track. It may, however, be rotated through 90 degrees, thereby producing a track of the variable density type. The Taguer system uses the Kerr Cell for recording, and the apparatus is manufactured by the Electrical Research Institute in Moscow. Both systems use the Reisz carbon microphone, of German origin.

### C. *Progress Notes from Miscellaneous Countries*

The language difficulty inherent in talking motion pictures has led to the production of pictures using the native tongue in many countries during the past year. Thus we find Turkey making a feature in native Arabic that had a four weeks' run. In Ireland, Louis Elliman, Ltd., will shortly present *Sweet Iniscara* with an all-Irish cast. In Spain, the Compania Española Americana, a recently created Spanish film company, has equipped a studio in Ciudad Linear with Klangfilm Tobis recording and reproducing sets. Another company by the name of Hispanophon has been created at Valencia to make joint Spanish-German productions. Film production at Sievering, Austria, has benefited by the very low cost of production. In Australia a company known as British National Films, Ltd., has been formed to produce sound pictures in that country. In Czechoslovakia, the Elekta Film Co. plans to coöperate with the Gaumont F. F. A. of Paris, in order to produce sound features in Czech, German, and French versions. In Japan about 14 per cent of the total market consists of foreign films of all sorts, and of this amount at least 90 per cent consists of films in which the sense of the scene is conveyed by superimposed titles in Japanese. In the smaller cities, and in the smaller theaters of the larger cities, the native interpreter or "benshi" is still used. The Odeon Film, of Rome, is now working on the production of several shorts with

Arabian dialog illustrating scenes of Arabian life, and intended for distribution in Egypt, Turkey, Arabia, Syria, and Palestine.

The first Yugo-Slav film, called *The Coast of a Thousand Islands*, showing beautiful landscapes in Dalmatia, was recently exhibited in Belgrade. This film was made in two versions, Serbo-Croatian and German. In Sweden, a total of 30 feature productions was made during 1932. A large studio is being built in the vicinity of Sundyberg in which the recording and electric light installations will be supplied by the Dutch Philips Company.

**MOTION PICTURE THEATERS THROUGHOUT THE WORLD**

| | *Wired for Sound* | *Silent* | *Total* |
|---|---|---|---|
| Europe | 17,822 | 12,801 | 30,623 |
| U. S. A. | 14,000 | 5,042 | 19,042 |
| Latin America | 1,830 | 3,716 | 5,546 |
| Far East | 2,147 | 2,775 | 4,922 |
| Canada | 777 | 323 | 1,100 |
| Africa and Near East | 379 | 312 | 691 |
| Total | 36,955 | 24,969 | 61,924 |

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[13] U. S. Pat. 1,870,662; Brit. Pats. 364,852; 366,517; 373,004; Ger. Pat. 541,596.
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# REPORT OF THE SOUND COMMITTEE*

The Sound Committee has compiled in this report an outline of the major problems relating to sound recording and reproducing that require solution. Coördinated summaries of this sort, which necessitate first a broad and unbiased survey, may prove of value by emphasizing the limiting factors in the several branches of the industry whose inter-relationship is too often overlooked.

## FREQUENCY EXTENSION

The recording of a wider range of frequency on sound film brings into prominence certain problems that have heretofore been of considerably less importance. With high-frequency extension, distortion becomes more readily discernible, and film ground noise more noticeable. To prevent the former, several matters require consideration. Film propulsion in recording and reproducing mechanisms must receive attention, particularly as regards the 96-cycle sprocket hole effect. Overloading of any character must be more diligently guarded against. Detrimental effects introduced in printing should be recognized and corrective measures applied. While no new requirements have been introduced in film developing and printing, divergence from optimum conditions is more readily apparent. To combat ground noise, it is imperative to employ all possible refinements during film processing and all care in the preservation of the release prints themselves. With low-frequency extension, a-c. hum becomes a more important factor, and may necessitate in many cases more effective electrical filtering.

With wider frequency range, more realistic reproduction, particularly of music and sound effects, becomes a fact. The need for increase in volume range becomes increasingly urgent to effect naturalism.

## REVIEW ROOMS

Now that requirements for optimum listening conditions in auditoriums are fairly well known, a first effort toward standardization

* Presented at the Spring, 1933, Meeting at New York, N. Y.

of quality should be made by providing correct acoustic properties in the producers' review rooms. A producer's who views his product in incorrectly treated review rooms, or with equipment that is not representative of the best theater practice, may acquire a distorted impression of the sound quality that his studio is obtaining in its recordings. Furthermore, if the review rooms are faulty, the product itself tends to become changed in quality, since the sound departments will wish to make it sound well in the particular locations where the studio executives are most apt to listen.

While there are fundamental acoustic characteristics that differentiate large and small rooms which, on the basis of present knowledge, appear to preclude the possibility of making the acoustics of review rooms exactly simulate those of theaters, the producers can at least see to it that bad defects are eliminated from their review rooms. Indications are that at the present time many review rooms are too dead and should be more reverberant, not only in order to improve their own qualities but at the same time to make them more nearly approximate theater conditions. Many rooms do not have the desirably smooth "reverberation *vs.* frequency" characteristic, nor the advocated greater amount of liveness at the low frequencies. Some rooms have resonances that are most detrimental to proper listening conditions. There are many precautions that should be observed in such important places of critical judging that can best be attended to by the engineer after surveying and analyzing each individual room. By eliminating the acoustic deficiencies it would be possible to judge a picture on its own merits, without the danger of attributing to it defects inherent in the room itself, and also to obtain a better impression of the ultimate effectiveness of the picture in the theater.

Although many theaters still remain intolerable in their acoustic properties, the efforts of the studios should be directed toward providing a product suitable for the better houses, in the hope that the inferior theaters may have an incentive to improve their condition. The Sound Committee's report in the Spring of 1932 discussed broadly the need for acoustic correction in theaters. This subject can not be reiterated too often or too strongly.

### FILM PROCESSING

Although universal standardization of film processing may not be feasible at present, each producer should be in a position to formulate the requirements for best results with his own films, and should de-

mand that each reel of all release prints comply with specific requirements; and the film laboratories should on their part be capable of complying with the specifications of the producing studios. Even if these requirements should entail additional cost for the release print, the contrary of which is more likely true, the increase would be a small item in comparison with the total cost of the picture, and would be well justified by assuring that no defective or inferior release prints find their way into the theaters. Producers should bear in mind that their incomes are derived either directly or indirectly from the customer who pays to see and hear the release print in the theater, and not what the producers themselves experience in their own review rooms or in preview houses. A poor print supplied to an exhibitor, who judges it himself or hears about it from his patrons, may create a bias in the exhibitor's mind against the entire product of the producer who supplied it.

### SILENT CAMERA

The Academy of Motion Picture Arts and Sciences continues its search for a truly silent camera. While the introduction of directive pick-up devices has been of material benefit in many cases, a silent camera is still a very real need in the studios. The Society should cooperate with the Academy in any way possible if such assistance will expedite a satisfactory conclusion of the work.

### ECONOMIES

Effort toward decreased production costs is evidenced by economies in recording practices being employed in several Hollywood studios. Three methods are in use which briefly are:

(1) Recording sound on both sides of a 35-mm. film and then splitting the film through the center after it has been developed. This is usually referred to as the "split film" method.

(2) Splitting the standard film through the center prior to recording, by which method the 17.5-mm. film is employed from the start.

(3) Selecting choice takes from the sound negative prior to its processing and using the faulty sound track negative for printing dailies, tests, and other incidental purposes. This is sometimes called the "preselection" method.

Because of differences in methods of operation in the several studios, there seems to be no reason to standardize any particular method, as one of the three fits nicely into the existing routines of most studios without necessitating change.

### ACOUSTICS

At the 1932 Spring Convention in Washington, the Sound Committee was asked by President Goldsmith to study the question of studio *vs.* auditorium acoustics. The subject is complex, and no quantitative relation has yet been shown to exist between the two factors. The need of further study is indicated. The results of investigations that have been made to date have been briefly summarized as follows:

Mr. A. P. Hill[1] discusses the relation between reverberation times in theaters and reverberation times in studios where recordings are made. The treatment is abstract and mathematical, and not concerned with the phenomenon of achieving proper illusion in motion pictures. The problem is resolved into three main divisions: reverberation in the studio, reverberation in the set, and reverberation in the theater when the sound source is not cut off instantaneously, but decays at the rate existing in the recording studio. For the cases where the theater is comparatively "live" and the recording set is "dead," the resulting combined reverberation is not appreciably greater than would exist in the theater alone with an instantaneously cut off sound source. The greatest directly additive effect in reverberation occurs when the studio and the theater have approximately equal reverberation periods.

Reproduction of speech and music is not, however, entirely a matter of reverberation treated mathematically as a purely physical factor; psychological considerations play an important though illusory part. It seems that it is necessary, for best results, to maintain a close degree of correlation between what the ear appears to hear and the eye to see. Thus, while we know that articulation is best when recordings are made under highly dead conditions, the psychological impression is most satisfactory when the effective reverberation is made to correspond to that of the scene being depicted.

The question of illusion in recording is resolved by Mr. J. P. Maxfield[2] into two factors: one the distance of the recording microphone from the source, and the other the amount of reverberation existing in the set. The two factors mentioned here may be combined into one: the ratio of direct to reflected sound energy. On the basis of his recording experience, Maxfield gives curves showing the relation between the focal length of the lens used, and the placement of the microphone for three types of sets: live, average, and dead.

Mr. R. L. Hanson at the November, 1931, meeting of the Acoustical

Society of America discussed the causes of the sensation of liveness. He considers that monaural recordings are more live than would be expected from listening binaurally at the microphone position, owing to the fact that the intensity fluctuations resulting from the shifting interference patterns during sustained as well as decaying sound are in effect reduced by a binaural pick-up. The fluctuations in intensity must, therefore, be reduced in the monaural pick-up to make the two methods comparable in results. The employment of two microphones on a single recording channel does not, of course, accomplish this. Since the only feasible means of reducing such fluctuations is to use sets somewhat deader than natural and closer microphone locations than might otherwise be desired, we accept such compromise for monaural recording.

## PROGRESS

Theater reproducing equipment has remained substantially unchanged over a period of years while studio recording has progressively improved. The situation was rapidly approaching when the studios might feel it useless to improve their product further unless the theaters kept pace with better reproducing apparatus. Fortunately many theaters are at the present time being provided with equipment that accommodates a wider band of frequencies, with resulting improvement in the reproduction of both dialog and music. There is now a definite incentive for the studios to perfect their recording still further and be prepared to accept promptly any new advances that may be imminent. The knowledge that greatly superior sound records can be effectively reproduced by the theater equipment is an interesting situation that has probably not heretofore existed.

H. B. SANTEE, *Chairman*

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| M. C. BATSEL | C. L. LOOTENS |
| P. H. EVANS | W. A. MACNAIR |
| N. M. LA PORTE | W. C. MILLER |
| E. W. KELLOGG | H. C. SILENT |

S. K. WOLF

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[1] HILL, A. P.: "Combined Reverberation Time of Electrically Coupled Rooms," *J. Acoustical Soc. of Amer.*, **IV** (July, 1932), No. 1, Part I, p. 63.

[2] MAXFIELD, J. P.: "Some Physical Factors Affecting the Illusion in Sound Motion Pictures," *J. Acoustical Soc. of Amer.*, **III** (July, 1931), No. 1, p. 69.

# REPORT OF THE COMMITTEE ON STANDARDS AND NOMENCLATURE*

In order that the Standards Committee might be representative of the entire industry, an effort has been made to include in its personnel members connected with all the various branches of motion picture engineering, in order that the points of view in matters of standardization of all these branches be brought before the Committee; and to make the scope of the work of standardization as broad as possible, a number of the members of the Committee are chairmen of other committees of the S. M. P. E., which committees, dealing with specific subjects, are in a position to propose standards for consideration by the Standards Committee. In order to indicate the representative nature of the membership of the Standards Committee, therefore, there is appended to this report a list of the members, together with their commercial affiliations. In the few cases that infrequently arise in which an interest particularly concerned with the projects at hand is not represented on the Committee, an effort is always made to obtain the points of view of those interests on the subjects under consideration, either by correspondence or by inviting their representatives to attend meetings of the Committee as guests.

At the Washington Convention, in May, 1932, some discussion was held regarding the method of validating S. M. P. E. standards. The Standards Committee was requested to submit a method of procedure to the Board of Governors for its consideration. As a result of action by the Standards Committee, the Chairman submitted a letter to the Board of Governors under date of May 2, 1932. This letter, together with a proposal to circularize the entire membership of the Committee in order to obtain votes on proposals for standardization, was submitted to the Board of Governors at the meeting of July 7. The exact wording of the proposal submitted to the Board of Governors reads:

"It is proposed by the Committee on Standards and Nomenclature of the Society of Motion Picture Engineers that the following procedure be adopted, in order to establish for the Society a method of

* Presented at the Spring, 1933, Meeting at New York, N. Y.

validating and approving proposals for the standardization of motion picture materials, equipment, technic, acceptable practice, and dimension, definitions, and quantities relating thereto: that an adequate study of the problems at hand be made by the Committee, and that the adequacy of this study be established (1) by the largeness of the number of appointees to the Committee, (2) by choosing these appointees so that all important interests in the industry concerned with the questions at hand are represented on the Committee, and (3) that when it is difficult or impossible for all important interests of the industry to be represented on the Committee, or whose representatives can not attend the meeting of the Committee, the Standards Committee should communicate with those interests in order to obtain their opinions and arguments, before making any recommendation of standards.

"Having made such an adequate study, as outlined above, the Committee should discuss the proposals in meeting; if necessary, taking a tentative vote on the question at hand, in order to indicate whatever consensus of opinion there may be. This vote, however, should not determine the acceptance of the proposal. Final action on the proposal should be obtained by letter ballots, returned by all members of the Committee, to whom previously has been sent a transcript of the proceedings of the meetings at which the questions to be voted upon were discussed."

The Board of Governors acted upon the proposed method of validating standards and decided upon the following procedure:

"All proposals of standardization to be submitted to the Board of Governors must first receive the recorded affirmative votes of three-fourths of the entire Standards Committee received within thirty days from the time the voting ballots are mailed. Upon receipt of a report, approved in this manner by the Standards Committee, the Board of Governors will accept or reject the report; if accepted, it will be published in the next succeeding issue of the JOURNAL, accompanied by an invitation to the members of the Society to submit their comments on the report. At a meeting of the Board of Governors, occurring not sooner than thirty days after the publication of the report, the Board may consider these comments and take final action on the proposals, validating them as standards of the Society, or rejecting them."

At a meeting of the Board of Governors held on October 5, 1932, the following action was taken on the method of validating and ap-

proving and publishing reports and standards submitted by the Standards Committee:

"It is moved and passed that a majority affirmative vote of letter ballots received within thirty days on specifically stated recommendations of the Standards Committee should be authorization for early publication of corresponding material in the JOURNAL, with an adjoined request for comments from all those who are interested. It should be the duty of the office of the Society to bring all communications relative to the published recommendations to the attention of the Board of Governors at its earliest meeting. Such recommendations, if later approved by the Board of Governors, should be republished as S. M. P. E. recommended practice."

Since the last report of the Standards Committee, the Board of Governors has officially acted upon recommended standards for 16-mm. sound film. The dimensional data published in the JOURNAL of November, 1932, have therefore been approved as the official dimensions recommended by the Society, and these approved standards have been submitted to the American Standards Association for consideration.

As there are in foreign countries standardizing agencies interested in the motion picture field, it is obviously desirable that there be as close coöperation as possible between the S. M. P. E. and the foreign agencies. The principal international organization interested in standards for the motion picture field is the International Congress of Photography. Dr. Walter Clark of the Eastman Kodak Co., Chairman of the American National Committee, has appointed the Chairman of the Standards Committee of the S. M. P. E. as a member of the American National Committee of the International Congress of Photography. Dr. Clark has suggested that the S. M. P. E. Standards Committee might act in a sense as a sub-committee of the American National Committee in order to provide a channel for obtaining international consideration of proposals for standardization. It is understood that the Secretary of the American National Committee acts as a sort of clearing house between the committees in this country and the corresponding committees in other countries.

There has been some direct correspondence between the Chairman of the S. M. P. E. Standards Committee and the Chairmen of the Standards Committees in Germany, England, and France, regarding the interpretation of standards as published in the JOURNAL. In each

case, it has been possible to clarify the interpretation of our published data.

At the present time, there are active sub-committees dealing with sensitometric standards and with nomenclature. Mr. L. A. Jones is the chairman of the Sensitometric Standards Sub-Committee, and Professor A. C. Hardy is the chairman of the Sub-Committee on Nomenclature. Mr. Jones' sub-committee is preparing a preliminary report outlining the progress that has been made by the International Congress of Photography relative to sensitometric standards and explaining the fundamental constants that are being considered as suitable for standardization. Professor Hardy expects that his sub-committee will have a report completed by next fall.

At the present time, the Standards Committee has under consideration the following proposals, in addition to the subjects mentioned above, which are being considered by the sub-committees.

(1) A definite proposal to eliminate the present type of negative perforation and to use the present positive perforation for all negatives as well as positives.

(2) The revision of the Standards Booklet. All items in the booklet are being reconsidered at the present time, as some of the items are definitely in need of revision, and it is desirable to include additional standards and recommendations.

(3) Consideration is being given to the possibility of recommending certain standard sizes of projection screens.

(4) An attempt is being made to reach agreement on standard widths for reel hubs for use in projection equipment.

The Standards Committee will welcome suggestions from the membership at large in regard to suitable proposals for standardization.

M. C. BATSEL, *Chairman*
RCA Victor Co., Inc.

W. H. CARSON,
Agfa Ansco Corp.

L. E. CLARK,
Clarco, Inc.

L. DE FOREST,
De Forest Television Co.

J. A. DUBRAY,
Bell & Howell Co.

P. H. EVANS,
Warner Bros. Pictures, Inc.

R. M. EVANS,
De Luxe Laboratories, Inc.

N. M. LA PORTE,
Paramount Publix Corp.

D. MACKENZIE,
Electrical Research Products, Inc.

G. F. RACKETT,
Technicolor Motion Picture Corp.

W. B. RAYTON
Bausch & Lomb Optical Co.

C. N. REIFSTECK,
RCA Victor Co., Inc.

H. RUBIN,
Paramount Publix Corp.

R. E. FARNHAM,
General Electric Co.

C. L. FARRAND,
United Research Corp.

H. GRIFFIN,
International Projector Corp.

A. C. HARDY,
Mass. Institute of Technology.

R. C. HUBBARD,
Consolidated Film Industries, Inc.

L. A. JONES,
Eastman Kodak Co.

H. B. SANTEE,
Electrical Research Products, Inc.

V. B. SEASE,
Du Pont Film Mfg. Corp.

T. E. SHEA,
Bell Telephone Laboratories, Inc.

J. L. SPENCE,
Akeley Camera, Inc.

E. I. SPONABLE,
Fox Film Corp.

S. K. WOLF,
Electrical Research Products, Inc.

## DISCUSSION

MR. COFFMAN: From the point of view of the laboratory, the entire problem of control of not only printer slippage but the location of the sound track as well, is rather intimately connected with the change of perforation that is being proposed by the Committee. Such a change will have a great effect on the life of the negatives, for definite evidence is available that shows that the old negative perforation is much more subject to wear and tear in the process of printing than the present positive perforation.

# REPORT OF THE PROJECTION SCREENS COMMITTEE*

Since its last report, the Projection Screens Committee has engaged in studies of several matters pertaining to screens and projection practices, the most important of which are: standardization of sizes of manufactured screens, a simple method of determining reflectivity of the screen in the theater, and sound transmission characteristics of screens in connection with the extension of the range of frequency of reproduced sound. These, with other matters of interest, are discussed in the following sections.

## SCREEN SIZES

The Committee has been considering the possibility of standardizing screen sizes ever since it was organized. There are several reasons for standardization. According to manufacturers, the foremost advantage will be the elimination of errors arising in ordering and assembling screens. There is also the possibility of economy due to the fact that the process of assembling screens according to standard specifications may be resolved into a standard procedure. Another advantage is the inherent convenience of standards, as contrasted with haphazard, chaotic conditions. With these thoughts in mind, the Committee has prepared a list of screen sizes that appears to fulfill the requirements of simplicity and generality of application.

It will be noted that the key number designating the screen is made to correspond to the *width of the picture*. It is believed that the picture width, as a more fundamental quantity, represents a more appropriate selection for designating screen sizes than either the full screen width or the width of the frame. This also accords with the procedure for determining projection lenses. The full width of the screen, including the borders, will be about 5 inches greater, and the inside frame width an additional 8 or 10 inches, where the screen is laced to hook on the inside. In the event that a given screen has a picture width intermediate between two of the proposed standard sizes, the screen to be chosen shall be the larger size, if possible. In some cases, this might be desirable from the point of view of the audience, even

* Presented at the Spring, 1933, Meeting at New York, N. Y.

though it might necessitate alteration of the supporting structure. It is felt that a one-foot separation between sizes is small enough for most practical purposes, besides being convenient. The following table shows the proposed standards:

**TABLE I**

*Proposed Standard Screen Sizes*

| Size Number of Screen | Picture Width, Feet | Picture Height, Feet | Picture Height, Inches |
|---|---|---|---|
| 8 | 8 | 6 | 0 |
| 9 | 9 | 6 | 9 |
| 10 | 10 | 7 | 6 |
| 11 | 11 | 8 | 3 |
| 12 | 12 | 9 | 0 |
| 13 | 13 | 9 | 9 |
| 14 | 14 | 10 | 6 |
| 15 | 15 | 11 | 3 |
| 16 | 16 | 12 | 0 |
| 17 | 17 | 12 | 9 |
| 18 | 18 | 13 | 6 |
| 19 | 19 | 14 | 3 |
| 20 | 20 | 15 | 0 |
| 21 | 21 | 15 | 9 |
| 22 | 22 | 16 | 6 |
| 23 | 23 | 17 | 3 |
| 24 | 24 | 18 | 0 |
| 25 | 25 | 18 | 9 |
| 26 | 26 | 19 | 6 |
| 27 | 27 | 20 | 3 |
| 28 | 28 | 21 | 0 |
| 29 | 29 | 21 | 9 |
| 30 | 30 | 22 | 6 |
| 31 | 31 | 23 | 3 |
| 32 | 32 | 24 | 0 |
| 33 | 33 | 24 | 9 |
| 34 | 34 | 25 | 6 |
| 35 | 35 | 26 | 3 |
| 36 | 36 | 27 | 0 |
| 37 | 37 | 27 | 9 |
| 38 | 38 | 28 | 6 |
| 39 | 39 | 29 | 3 |
| 40 | 40 | 30 | 0 |

The proportion of width to height has been chosen as 4 to 3. For a projection angle of 18 degrees, which represents an average condition,

this ratio will require a minimum amount of masking on the basis of the new standard aperture. For other angles, more masking will be necessary. If, however, a $4^1/_8$ to 3 screen ratio were standardized, it would be theoretically correct for horizontal projection only, and would require an increasing amount of masking and a correspondingly greater amount of unused screen surface. The 4 to 3 ratio has the further advantage that a large number of existing frames are made to accommodate screens of such shape. Another advantage is the simplicity of the ratio and the ease of computing heights from widths.

It was thought that after standardizing on sizes, manufacturers would be required to stock only a relatively small number of screens. The Committee is informed, however, that this would be impracticable inasmuch as deterioration would soon set in. For this reason, it has been customary to make screens to order.

The Committee also recommends that the standard spacing of grommets be 6 inches, with 12 inches as a possible sub-standard. Some frames are designed for a 12-inch spacing, but these will also accommodate the primary standard. The smaller spacing permits a more even distribution of tension, which is especially desirable at the top of the screen. When assembling a screen, the first grommets should be placed in the center of each side and the process then extended to the edges. The screen, when mounted, should not be stretched too tightly, but some slack should be allowed to exist to compensate for changes produced by atmospheric conditions.

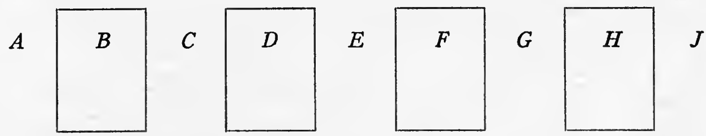
### SCREEN IMAGE DISTORTION

The discussion incidental to the adoption of the new standard aperture has helped to focus attention on the problem of screen image distortion. Such distortion involves three elements: the projection angle, the observation angle, and the size of the screen. Indirectly involved is the distortion occasioned in photographing or viewing the original scene. Masking a projected picture will avoid keystoning at the edges; but, of course, it will not improve the distortion within the image itself. A thorough exposition of these factors, with an estimate of their seriousness, would be an important contribution to motion picture engineering. The Committee therefore proposed to one of its members that he undertake the preparation of a paper on the subject. Mr. C. Tuttle, of the Eastman Kodak Co., kindly consented to

## *B.* REFLECTION FACTOR = 0.43

### DIRECTIONS FOR DETERMINING SCREEN REFLECTIVITY

(1) Remove these four pages from the Journal and pin them to the projection screen, the plain sides facing the audience. They should be arranged as shown below, in the order *B, D, F, H,* leaving a distance of about six inches between each sheet.




(2) The screen should next be illuminated, either by light from the projector or by general auditorium illumination. A portion of the screen that is uniformly clean should be chosen, and the illumination of that portion should be fairly uniform.

(3) From a distance sufficiently great that the perforations of the screen can not be distinguished (at least twenty feet from the screen), compare the brightness of the screen with the brightness of the paper samples. Usually, the reflectivity of the screen will lie between the reflectivities of two of the samples; occasionally it will approximate very closely the brightness of one of the samples. When the screen is brighter than *H* it is in excellent condition; when it is duller than *B* it is unsatisfactory. For convenience in transmitting the data to the Committee, the reflectivity of the screen should be graded according to the letters in the diagram above. For example, if the reflectivity of the screen should lie between the reflectivities of samples *B* and *D,* the reflectivity of the screen should be graded as *C;* if the reflectivity of the screen approximates very closely that of sample *D,* then it should be graded as *D;* and so on.

(4) This simple comparison method should be applied only to screens of the diffusive (flat white) type, and then should be made by viewing the screen at several angles within a range of 40 degrees from the normal to the screen. A special technic is required for beaded and metallic screens.

(5) The Projection Screens Committee would like to be informed of the results of measurements made with these samples. Please address the Chairman of the Projection Screens Committee, at the General Office of the Society of Motion Picture Engineers, 33 West 42nd St., New York, N. Y., giving the following information: trade name of screen, name of manufacturer, age of screen, how long ago the screen was last resurfaced, a statement of the general condition of the screen, and the kind of ventilating system used in the theater.

Report of the Projection Screens Committee, Journal of the Society of Motion Picture Engineers, **XX,** No. 6, June, 1933.

B

D. REFLECTION FACTOR = 0.52

Report of the Projection Screens Committee, Journal of the Society of Motion Picture Engineers, **XX**, No. 6, June, 1933.

*D*

*F.* **REFLECTION FACTOR = 0.60**

Report of the Projection Screens Committee, Journal of the Society of Motion Picture Engineers, XX, No. 6, June, 1933.

# F

*H.* **REFLECTION FACTOR = 0.78**

Report of the Projection Screens Committee, Journal of the Society of Motion Picture Engineers, **XX,** No. 6, June, 1933.

*H*

do this and prepared a paper on the subject for presentation at the Spring Meeting of the Society.*

### DETERMINATION OF SCREEN REFLECTIVITY

The Committee has been seeking for some time a simple, practical method for exhibitors to determine the reflectivity of their screens. The most feasible method at the present time appears to be a direct comparison of the screen with samples of paper having known reflection values. The brightness of each sample is compared with the brightness of the screen; the reflectivity is determined from the sample whose brightness most nearly matches that of the screen, the several samples being calibrated in terms of reflectivity. The information so obtained, while not strictly accurate, is reliable enough to give the exhibitor, in a simple manner, the information he needs. It can serve either as assurance that all is well, or as a warning that his screen should be resurfaced or replaced in order to avoid excessive waste of light. With screens of the beaded and diffusive type, this simple comparison principle will not be very satisfactory because of the specular nature of the reflection.

To illustrate the method, there are incorporated in this report four samples of paper having the following graded reflectivities: 0.78, 0.60, 0.52, and 0.43. The values chosen were determined partly by the availability of the paper stock and partly with the thought of achieving a scale on the basis of which a screen might be called good, fair, poor, or unsatisfactory.

### SCREEN BRIGHTNESS

The proceedings of the "Commission International de L'Eclairage," eighth session, published in Cambridge, England, were recently brought to the attention of the Committee. These proceedings contain reports of German and Japanese sub-committees on theater illumination which should be of interest to American motion picture engineers.

The Japanese sub-committee recommended that the general illumination of the theater be not less than the amount required for reading programs printed in 8-point type. The value proposed in compliance with this requirement is about 0.18 foot-candle. This compares with 0.1 foot-candle found by the S. M. P. E. Theater Lighting

* "Image Distortion in the Projection and Viewing of Motion Pictures," presented at the Spring, 1933, Meeting at New York, N. Y., and to be published in the JOURNAL in the near future.

Committee[1] in 1931 to be adequate for locating seats easily after the eyes of the patron had accommodated themselves to that level of illumination. With the auditorium light at 0.18 foot-candle, the Japanese found that a screen illumination of 9.3 foot-candles was sufficient to preserve picture contrasts, with higher values not objectionable. This finding included the observation that care had to be exercised to prevent auditorium light sources from illuminating the screen directly and from shining into the observers' eyes.

According to the report, measurements made in eleven of the principal theaters of Tokyo showed screen illumination varying from 3.1 to 9.8 foot-candles, without film and shutter. The average was 6.35 foot-candles, considerably below the recommended value. In comparing these values with measurements made in America, it must be remembered to differentiate them from those of our measurements made with the shutter running. Shutters reduce the average brightness by 50 per cent, although the brightness during the illuminated intervals remains unchanged. The reflectivities of the screens were comparable with those of American types of screens.

The German sub-committee reported that it is not customary in their country to provide any general illumination other than that furnished by reflection of projected light from the screen. Screen illumination measured in ten theaters varied from 6 to 16.8 foot-candles at the screen centers, presumably without film, shutter condition not mentioned. The corresponding values for screen brightness ranged from 2.61 to 9.6 foot-lamberts.

## PERFORATIONS IN SCREENS

The acoustic transmission characteristics of screens are being reexamined, relative to recent developments on extended recording and reproduction frequency ranges. Difficulties are anticipated for only the higher frequencies. When the Committee first reported on the subject of screen transmission, it included the statement that screens that are satisfactory up to 6000 cycles are usually found to attenuate less than 4 db. at 10,000 cycles. Inasmuch as this value does not represent excessive attenuation, and since lesser amounts would be difficult or impracticable to obtain with commercial screens, the Committee feels that it can recommend it as representative of good practice. Some screens hitherto adjudged satisfactory will not be altogether acceptable for use with reproducing systems of wide frequency range.

There has been considerable discussion as to the advisability of devising some means of eliminating the necessity for perforations in screens. Both sound transmission tests and acoustic theory indicate the necessity for perforations. Recently, tests were made at the Bell Telephone Laboratories of a series of screens identical in all respects except as regards the number of perforations. One screen, without any perforations whatsoever, showed excessively large attenuation, especially at high frequencies. The others, with graded amounts of open area, showed increasing efficiency of sound transmission.

Since it is thus evident that perforations are necessary when the loud speakers are placed directly behind the screen, the question arises as to whether it would be possible to place the loud speakers to one side of the screen. In the past, this method has been tried and apparently found wanting, inasmuch as the practice has been discontinued. One difficulty was loss of illusion; another was that the method lacked the mechanical simplicity and flexibility inherent in "flying" the speakers, or mounting them on towers behind the screen so that they could be removed at will. The present standard method seems to meet most operating demands comparatively satisfactorily, although it also has its disadvantages.

One objection to the perforations is the loss of screen brightness that they cause: 5.8 to 8.5 per cent, depending upon the make of the screen. This loss is, of course, undesirable, especially when the available illumination is already scant. Another objection sometimes offered is that the perforations may be visible from the auditorium and thus mar the appearance of the projected picture. However, when the limiting distance for the visibility of the holes is computed from their diameter and the known resolving power of the eye, it appears that this consideration will be usually unimportant. A large value for the diameter of the perforations is 0.0625 inch; the resolving power of the eye may be taken as 1 part in 3438.[2] The limiting distance at which the perforations are just discernible is, therefore, 18 feet. Many makes of screens have perforations of smaller diameter which are, therefore, visible only within correspondingly shorter distances.

S. K. WOLF, *Chairman*

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|---|---|
| E. R. GEIB | A. L. RAVEN |
| H. GRIFFIN | R. T. RASMUSSEN |
| J. H. KURLANDER | H. RUBIN |
| W. F. LITTLE | C. TUTTLE |

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[1] "Report of Theater Lighting Committee," *J. Soc. Mot. Pict. Eng.*, **XVI** (Feb., 1931), No. 2, p. 239.

[2] HARDY, A. C., AND PERRIN, F. H.: "The Principles of Optics," *McGraw-Hill Book Co.*, New York, 1932, p. 190.

## DISCUSSION

MR. RICHARDSON: Perforations in screens vary in number from 25 to 40 per square inch; and they also vary in size. If screens are to be perforated at all they should all have the same number of perforations to the square inch, and all perforations should be of the same diameter.

As for testing screens, I have suggested many times that when exhibitors purchase new screens they should also obtain a sample of the material that can be stored in a dry dark place, wrapped in black cloth, so that at any time the surface of the screen may be compared with that of the carefully preserved sample.

The proposed plan of using differently colored samples of paper for comparison appears to be good, but the paper must be carefully selected so that it does not become discolored with time; and exhibitors must be warned to keep the samples wrapped in black cloth and in a dry dark place. However, if the screen be tinted as many screen surfaces are, comparison with paper samples will hardly serve.

MR. LITTLE: Paper samples entirely devoid of color would, of course, be preferable. However, with a little practice brightness matches can be made quite accurately. The problem of keeping the paper samples clean is not difficult, *i. e.*, they may be kept within the pages of the book. If they become soiled or discolored, new samples may be obtained; or if in the JOURNAL, by repeating the issuance from time to time, the exhibitors will always have clean sheets of paper available. It is hoped that some of the screen manufacturers will see the value of such sheets and will themselves arrange for their distribution.

MR. RICHARDSON: But does not paper contain chemicals that cause it to become discolored?

MR. LITTLE: The discoloration or change of reflection factor of the samples due to aging is as a rule very small. Samples in our possession have remained constant within 2 or 3 per cent for a period of at least ten years.

## REPORT OF THE STUDIO LIGHTING COMMITTEE*

Owing to the wide dispersion of the members of the Studio Lighting Committee the report of the Committee has this year been compiled from information obtained from the various manufacturers of equipment regarding developments in light sources, and the heads of electrical departments in the various studios as regards current practice and operation.

### ARC CARBONS

The manufacturers of arc carbons have carried on extensive developmental work in producing carbons suitable for illumination in connection with the production of colored motion pictures. A new automatic arc mechanism that will comply with the requirements of present studio operation is undergoing development; and although the work has not yet reached the stage at which a complete report is available, the manufacturers are much encouraged over the results that have been obtained.

The arc carbons that have been developed for the new mechanism are of small diameter and have been designed to produce a flaming arc of high intensity.

### VAPOR LAMPS

The manufacturers of vapor lamp equipment have produced sodium arc tubes that are claimed to have three to four times the luminous efficiency of incandescent lamps of corresponding wattage rating, and while the investigations of this Committee do not reveal any apparent practical application of the sodium arc to studio lighting, yet it seems advisable that the new developments in this kind of vapor lighting should be mentioned in the report. At present the spectral characteristics of this arc do not accord with the film sensitivity, but modifications of either the illuminant or the film stock might in the future cause the sodium arc to be of use in the motion picture industry.

### INCANDESCENT LAMPS

The development of bi-post construction for high-wattage lamps has been an outstanding contribution by the manufacturers of filament

* Presented at the Spring, 1933, Meeting at New York, N. Y.

lamps. Referring to Fig. 1, it will be noted that the new bi-post construction changes the basing of the lamp so as to eliminate the cemented prong base that has heretofore been supplied by the various manufacturers. The new design permits adherence to much closer manufacturing tolerances in constructing the lamp than previously, and combines all the advantageous features of previous developments with numerous other features that contribute to its ruggedness and longer life.

The success of the small photoflood lamp has encouraged manufac-

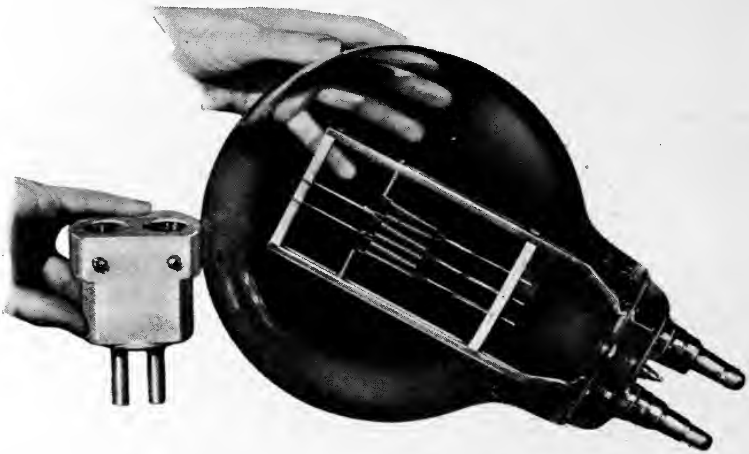

FIG. 1. Showing the new bi-post construction for high-wattage incandescent lamps; also the new adapter for the 5-kw., bi-post lamp.

turers toward the development of similar lamps of higher wattage. High-intensity lamps of this type consuming approximately 1500 watts, have been tried out and have provided a luminous efficiency of 34 lumens per watt, which is about the same efficiency as that of the photoflood lamp. The availability of such super-photoflood lamps would be of advantage to the studio lighting technicians in solving some of their difficult illumination problems.

## STUDIO PRACTICE AND OPERATION

There has been no great change in the past year in the lighting practice of the studios. The use of the super-speed film has considerably reduced the intensity of lighting required for exposures, has resulted

in a decrease of wattage, and has greatly enhanced the photographic results. The super-speed film required the elimination of spill-light from the back-lighting units, and thus caused the introduction of spill rings for masking off the unprojected light of the reflector units.

The improvement of sound recording technic has obviated some of the restrictions heretofore imposed upon the use of arcs. Where scenes require sharp shadows or strong contrast, and where large night sets are being photographed, the carbon arc forms a source of illumination that has not been excelled by any other source. The introduction of the 5-kw., bi-post incandescent lamp has altered the standard heretofore followed as regards bases for this size of globe.


FIG. 2. A 4-hole plugging box, 3-wire connected for eight low-power units or four 5-kw. units.

In days when every item of expense is frowned upon, it is necessary to provide a simple means of adapting the new lamps to the existing equipment, and to bridge over the transition from the old design to the new. To meet this situation, one of the equipment manufacturers has developed a simple adapter, shown in Fig. 1, which permits the 5-kw., bi-post lamp to be used in existing equipment of all types.

The past year has seen some improvements in current distribution facilities on motion picture stages. A number of stages have been equipped with remote control switchboards mounted on the overhead runways, to which are permanently connected distribution networks of cables terminating in lightweight 4-hole plugging boxes. It is

standard practice in the studios to equip incandescent lighting apparatus with what are called "inkie" plugs; these plugs having half the thickness of the standard stage plugs, thus permitting two plugs per hole in the standard stage receptacle. The 4-hole plugging box illustrated in Fig. 2 is 3-wire connected, and allows the use of eight low-wattage units or four units of 5-kw. capacity each. In studios that have been employing this system, very considerable savings have been made owing to the reduction of the time required for the rigging and striking of lighting equipment on sets.

The low ebb of production activity during this period of economic retrenchment has somewhat limited the development of new types of equipment. No new equipment has been forthcoming that has had any major effect upon general lighting practice.

P. MOLE, *Chairman*

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| L. J. BUTTOLPH | C. W. HANDLEY |
| R. E. FARNHAM | J. H. KURLANDER |

W. J. QUINLAN

# REPORT OF THE PROJECTION THEORY COMMITTEE*

Under the present organization of the Society, there are three projection committees: namely, the Projection Screens Committee, the Projection Practice Committee, and the Projection Theory Committee. Since it is the primary function of the Projection Theory Committee to deal with the optical principles involved in the projection of motion pictures, the work of this Committee does not lend itself to the usual type of progress report. The optical principles have long been established—so long, in fact, that they are seldom discussed in the current literature. Instead, one must look for them in advanced works on optics, which ordinarily contain so much irrelevant material that a full understanding of the theory of optical projection is not easily acquired. The Projection Theory Committee feels that it can be of greatest service to the Society by preparing a short monograph on the theory of projection. This monograph will discuss the function of the light source, the condenser, and the projection lens; will analyze the requirements that must be met if these units are to work together effectively; and will indicate, by a discussion of the photometry of optical instruments, the method of obtaining the maximum illumination of the screen with a given source of light. As this report is written, the monograph is in outline form, and will undoubtedly be completed during the coming summer.

Many of the problems involved in the projection of motion pictures require careful coördination of theory and practice. During the past year an attempt has been made to achieve this coördination through the collaboration of the chairmen of the three projection committees. Although this arrangement has been very successful, it involves much wasted effort. It is felt, therefore, that with the reorganization of committees at the time of the next election of officers, it would be well to combine the three committees into a single projection committee. This committee might well have a large membership, to permit division into sub-committees to deal with specific problems. This plan would obviate the necessity of dividing the problems arbitrarily

* Presented at the Spring, 1933, Meeting at New York, N. Y.

into those that are primarily theoretical, those that are primarily practical, and those that pertain primarily to motion picture screens.

A. C. HARDY, *Chairman*

R. E. FARNHAM W. F. LITTLE

H. P. GAGE W. B. RAYTON

C. TUTTLE

DISCUSSION

MR. F. H. RICHARDSON: Has the Committee investigated the losses that occur in projector optical systems, including the loss at the spot and that due to the rotating shutter?

MR. A. C. HARDY: The Committee hopes to discuss that subject in its next report.

# REPORT OF THE COMMITTEE ON THE PRESERVATION OF FILM*

This Committee was appointed for the purpose of collecting data and information pertaining to the preservation of all types of film such as might be produced by the motion picture industry; but, particularly, to collaborate with the supervising architects of the new Government Archives Building which is in course of construction under the direction of the Treasury Department of the United States.

Two formal meetings of the Committee were held during 1932: one in New York, held on April 15, at the offices of the Motion Picture Producers and Distributors of America, Inc., and one at Washington, D. C., on September 12, in the office of Mr. Raymond Evans, chief of the Office of Motion Pictures of the U. S. Department of Agriculture.

At the latter meeting we were fortunate in having present representatives of the office of the Supervising Architect, as well as representatives of various branches of the government that might be affected by any recommendations made by this Committee, and which, under the present understanding of the plan for film preservation, might have more or less film to be turned over to the Archives. These representatives were: Louis A. Simon, of the Office of the Supervising Architect, Treasury Department; Lt. Com. R. A. Hyde, of the Navy Department; Capt. F. W. Hoorn, of the U. S. Signal Corps; Mr. A. E. Kimberly, Research Associate, Bureau of Standards, Department of Commerce; and Mr. C. J. North, of the Department of Commerce.

Subsequent discussion, by correspondence and at a meeting held during the Spring, 1933, Convention at New York, N. Y., of the terms of the report as originally drafted led to the final report as here presented.

This report in addition to being submitted to the Society as the annual report of the Committee, will be forwarded to the supervising architect's Office of the Treasury Department as containing the Committee's recommendations to date on the problems at hand.

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

The first approach of the Committee to this problem indicated immediately a lack of definite understanding as to the scope of the recommendations to be made. It was, therefore, the consensus of the Committee that the members discuss the problem among themselves from the broadest possible application; and Mr. Milliken, who is familiar with the plans of Mr. Will Hays—who has been directly in contact with President Hoover in this matter—outlined to the Committee his understanding of the general situation.

At the time of the earlier meeting of the Committee, it was not possible to obtain definite information as to the space available for storing film; and it seemed necessary, therefore, that at some future date, a committee from the government definitely select from the available material that which should be stored, according to the amount of space ultimately allotted for the purpose.

At the second meeting the Committee was informed by Mr. Simon that, under the terms of the bill that had authorized the construction of the Archives Building, there was some question as to whether film other than that now in the possession of the governmental departments, or in the future produced by them, would be included among the archives, although he expressed the wish that the Committee present the question of providing additional space to accommodate other classes of film that might be recommended, if it were found practicable. The Committee, therefore, discussed the form and required capacity of such vaults as would be required, and arrived at the following conclusions:

*Air Conditioning.*—It is recommended that provision be made in the vaults for air conditioning equipment so as to maintain a temperature of approximately 60°F., and a relative humidity of 60 per cent.

(Early recommendations suggested a temperature of 40° to 50° and a relative humidity of 60 per cent. However, it was pointed out that film stored under climatic conditions as encountered in Washington would absorb moisture when brought into rooms subject to ordinary atmospheric conditions, and that it would be necessary to construct in connection with the vaults some sort of a tempering room in which the outside temperature that the film would encounter would be maintained at a very low humidity until the temperature of the film itself had been raised to normal room temperature.)

The following chart was submitted by Mr. H. T. Cowling, showing a record of temperature changes in the City of Washington over the past 33 years:

| Absolute Temperature | | | Average Temperature | | Relative Humidity | | |
|---|---|---|---|---|---|---|---|
| Low | High | Mean | Min. | Max. | 8 A.M. | 8 P.M. | |
| 14 | 76 | 33.7 | 25.7 | 41.2 | 67 | 76 | Jan. |
| 15 | 78 | 34.7 | 26.6 | 43.0 | 63 | 73 | Feb. |
| 4 | 93 | 42.6 | 33.8 | 51.4 | 61 | 74 | March |
| 22 | 95 | 53.4 | 43.3 | 63.0 | 58 | 69 | April |
| 33 | 96 | 64.2 | 53.9 | 74.1 | 58 | 73 | May |
| 43 | 102 | 72.4 | 62.9 | 82.2 | 70 | 76 | June |
| 52 | 103 | 76.8 | 67.6 | 86.4 | 71 | 79 | July |
| 49 | 106 | 74.4 | 65.7 | 83.8 | 74 | 80 | Aug. |
| 36 | 104 | 68.0 | 58.9 | 77.8 | 76 | 81 | Sept. |
| 26 | 92 | 56.9 | 46.9 | 66.3 | 72 | 81 | Oct. |
| 12 | 80 | 45.2 | 36.6 | 53.8 | 66 | 77 | Nov. |
| 13 | 73 | 36.1 | 28.4 | 44.0 | 66 | 76 | Dec. |
| | | 54.9 | 45.9 | 63.9 | 68 | 76 | Annual Average |

In order to facilitate the maintenance of uniform atmospheric conditions, it was recommended that the vaults be placed below ground, and that they be so vented as to maintain a pressure above the outside pressure at all times. This would lead to a movement of the air toward the outside, and would avoid condensation within the vaults due to seasonal changes of temperature.

The next question concerned the best manner of preserving film under all the conditions to which it would be subjected, including the personal influences. First of all, the film as submitted for storage in the Archives Building should be tested to determine its condition as regards freedom from injurious chemicals due to faulty or careless processing; and, if found to be faulty in this respect, it should immediately be subjected to approved methods of rewashing and testing. It was pointed out that this could be done by any of the well-equipped laboratories in Washington, and that facilities for so doing need not be considered as part of the equipment of the Archives Building. Although no definite recommendations were made as to the details of such a test, attention was called to an outline of these details published previously in the JOURNAL.[1,2] It was agreed by the Committee that any of the recommended practices for the cleaning of film should prove satisfactory to meet the circumstances.

*Film Containers.*—It is recommended that the film for permanent storage be enclosed in a container made of non-corroding metal or fiber board. It was pointed out that it was advisable that these films should not be hermetically sealed, as this would prevent the escape of any decomposition products or solvent contained within the

film itself. These containers could be especially constructed to accommodate rolls 1000 feet long or any greater convenient length.

*Film Cabinets.*—Within a vault conforming to the existing regulations of the Fire Underwriters, except as regards its capacity, which the Committee considers could be two or three times that of the maximum allotted space of 750 cubic feet, provided that the total weight of film within the vault does not exceed that permitted by the Underwriters (10,000 lbs.), should be built a series of cabinets consisting essentially of racks or shelves made of some non-inflammable and non-conducting material such as impregnated wood or sheet asbestos. Each shelf should contain one unit reel, and the film should be stored at all times in such a manner that the roll is flat, thus avoiding uneven pressure within the roll on account of its own weight. The roll of film should be wrapped in chemically inert fluffless paper, and placed in an unsealed container of non-corroding metal, or fiber board. The shelves of the cabinet should be appreciably longer than the width of the film roll, and closed at the front end either by a common door or individual doors. At the other end, a space should be allowed between the edges of the shelves and back wall of the cabinet, so as to provide an air chamber through the entire cabinet which, in turn, should be connected to the outside air by means of a vent having a capacity as recommended under the existing regulations of the Fire Underwriters. This arrangement will assure a minimum loss of film in the event of fire within the cabinet.

*Water Sprinkler Equipment.*—There is considerable question, because of the comparatively recent development of nitrocellulose as a supporting base for photographic film, as to the danger of fire arising from spontaneous combustion; and vaults constructed as recommended, and maintained at the proper temperature and humidity as mentioned before, would largely eliminate danger from internal fire. The only other point to be guarded against, therefore, involves the possibility that the attendant may permit some condition to arise, either within the system or from without, that might lead to fire. In discussing the matter of the preservation of film, it is just as important that the film be guarded against damage by water or any other physical agent as to guard it from fire; and, if, in attempting to safeguard the film from fire it be subjected to damage by water, the end desired will not be accomplished. The Committee, therefore, recommends that some thought be given to the danger

inherent in the use of sprinkler heads in film vaults designed for storage of valuable negatives. Unless some adequate measures be adopted for carrying off the water, so as to prevent it from accumulating, it is felt that sprinkler heads would be a menace to the film.

While considering this matter, the Committee inspected the vaults belonging to the Signal Corps at the War College, and those belonging to the Department of Commerce in the new Commerce Building in Washington, and the following conclusions were reached in the cases of these two vaults:

*Signal Corps Laboratory.*—The arrangement and general construction of the vault were approved by the Committee, but the use of sprinkler heads at the top of each vault without provision for scuppers or other means of allowing the water to run off constituted a hazard.

*Commerce Department Vault.*—The vault as constructed is subject to all sorts of outside influences, both human and atmospheric, so that it is necessary to protect the film against fire in small unit quantities. The cabinets, made especially for this purpose for the Department of Commerce, are adjudged to be fully satisfactory for the purpose they serve; but it is felt that they represent unnecessary expense and occupy too much space for the storing of film under the anticipated controlled conditions that will prevail in the Archives Building. Furthermore, they require that the can of film stand vertically, a feature against which the Committee strongly advises.

*The Arrangement and Availability of Archives Film.*—For maintaining in a usable condition all motion picture film to be preserved, it is advisable so to arrange the handling of the film that it will be disturbed as infrequently as possible. It is, therefore, the recommendation of the Committee that upon receiving a film on any subject from any Department of the government or other source, if this film be in the form of a negative, a master positive and duplicate negative be made from it immediately, to be stored separately from the original film as a file copy and to be used for making subsequent prints as desired without disturbing the original negative. In case the film received is a positive, then two duplicate negatives should be made, one to be placed permanently in storage, the other, as described above.

Sixteen-millimeter copies should be made by reduction from each of the 35-mm. films in the Archives, and made available for current purposes of projection as required; subsequent 16-mm. file

copies to be made from the duplicate negative as shall be found necessary.

Periodic inspection of the original negative copies should be made at long intervals, to determine the condition of each individual film: by long intervals is meant a period of not less than one year or more than five years. Each film should be carefully inspected at the end of each interval in order to determine whether the film base is showing signs of deterioration, or whether the emulsion is adhering to the base. Measurements should also be made to determine the amount of shrinkage that has taken place. If it is found on inspection that the film is showing marked shrinkage, which would tend, if continued, to make it impossible to make prints from it, a new master positive should be made at once so that the pictures contained on the film shall at all times be available for future use.

*Conclusion.*—There are numerous factors having a direct bearing on the preservation of film that have not been discussed by this Committee, such as the possibility of transferring pictures to some medium, other than nitrocellulose film, of whose permanency we are certain, such as copper or noncorrosive metals.

As yet no study has been made of methods of storing film in other countries, where archives are already in existence. It is the intent of this Committee to continue its study until all matters of this kind have been fully investigated.

Mr. Simon expressed his satisfaction at the work of the Committee, and requested the privilege of seeking the services of this Committee and its members at any future time that further questions might arise in connection with the construction of the Archives Building.

W. H. CARSON, *Chairman*

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|---|---|---|
| H. T. COWLING | R. EVANS | J. M. JOY |
| J. I. CRABTREE | C. L. GREGORY | T. RAMSAYE |
| A. S. DICKINSON | | V. B. SEASE |

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[1] CRABTREE, J. I., AND ROSS, J. F.: "A Method of Testing for the Presence of Sodium Thiosulfate in Motion Picture Films," *J. Soc. Mot. Pict. Eng.*, **XIV** (Apr., 1930), No. 4, p. 419.

[2] CRABTREE, J. I., AND IVES, C. E.: "The Storage of Valuable Motion Picture Film," *J. Soc. Mot. Pict. Eng.*, **XV** (Sept., 1930), No. 3, p. 289.

## REPORT ON METHOD USED BY THE GERMAN GOVERNMENT FOR STORING MOTION PICTURE FILM

*The following is a contribution to the report of the Committee on the Preservation of Film by Mr. Erich Ewarth of Berlin, made at the instance of Mr. J. M. Joy, a member of the Committee.*

New methods of storing film have not yet been developed. I visited the patent office several times without any success in finding anything, and my searches in the libraries have also been in vain.

I wrote to and visited the *Reichsarchiv* (the archives, or record office of the *Reichsarchiv*) at Potsdam, where are stored all important films, positive and negative. The storehouse itself is rather simple; formerly a small brick stable, it has been adapted for the new purpose by the installation of iron and wooden shelves.

I had a long talk with the head of the film department, and Senior Councillor Ruppert, who told me that the *Chemische Technische Versuchsanstalt* (laboratory for chemical technical research) of the government had been asked to recommend the best and most scientific method of storing films.

The information was received that such a method did not exist. However, the stable was rebuilt, and the films are now being kept in the following manner:

Each film roll is put into a cardboard box made of waterproof "Vulcopa" (a fiber-like material); into the box is laid a piece of camphor (about 3 × 2 × 1 inches), which is renewed from time to time. (Tin containers are not used as the camphor must be allowed to volatilize into the open.) No more than five boxes are placed one on top of the other. The positives and negatives are carefully inspected at least twice a year.

Among numerous positives and negatives that I was allowed to inspect was a picture taken in 1913. I was astonished to find both positive and negative perfectly satisfactory; fresh, smooth, and unshrunk, as I proved by comparison with a piece of fairly new raw material.

As I was told, the humidity of the air is always about 70 to 80 per cent, due to the fact that many lakes are close by. The temperature in the storehouse is said to be about 20° to 22°C. in summertime, and not less than 10°C. in the wintertime. Those in charge are convinced that the films can be kept in absolutely proper condition for at least 30 to 40 years. At *Reichsarchiv* the old simple camphor method works so well that it is followed by some of the great cities, for instance, Bremen.

(Signed) ERICH EWARTH

The following are particular points of interest concerning the method of storing the film:

(1) The interior of the building was made dark by enclosing the windows, as experience had shown that light affected the condition of the film unfavorably.

(2) Shelves were built along the walls and in the middle of the room.

(3) No attempt was made to regulate the temperature, although it was thought that an improvement would result if the temperature were maintained constant at about 20°C.; this has not been done because of financial considerations.

(4) The best value of relative humidity is thought to be 60 to 70 per cent.

(5) Boxes for storage are square and all are of the same size, and may contain up to 400 meters of film. The camphor is placed in one corner of the box and is wrapped in paper to keep it from making contact with the films. Pure camphor is used.

(6) No chemical action occurs between the camphor and the base or emulsion. The camphor replaces the original content in the base.

(7) The camphor in each box is renewed twice a year.

(8) Fifty to sixty thousand meters of film are stored in this room. No special attention is given to winding the films except to wind them more loosely than ordinarily. The film is stored flat, not more than five boxes being placed one above the other.

(9) All film is inspected twice a year, and if any white spots are found they are wiped off with a cloth. This white deposit does not injure the film.

(10) Both positive and negative are handled in the same way. The method described has been followed for fifteen years.

(11) Water in sponges has been experimented with, but with unsatisfactory results.

## REPORT OF THE MUSEUM COMMITTEE*

The work of this Committee in preserving the traditions and relics of the motion picture has gone steadily forward during the past year. A majority of the pioneers of the industry are represented by relics of their endeavors in this collection, which is being brought together under the sponsorship of the S. M. P. E.

All phases of the industry are represented, and the exhibits are so arranged and labeled at the Los Angeles Museum that either a student or a casual visitor will benefit from a visit to the collection.

A few of the more important accessions to the collection that have been placed on display are the miniature sets enclosed in diorama cases. There are two of these sets: one representing a sound stage in operation, wherein is shown in scale all the paraphernalia necessary for shooting a sound picture; and the other showing the technic of shooting a glass process shot. This last-named set was arranged by Mr. Willis O'Brien, whose most recent picture was *King Kong;* in it are shown the elements necessary in creating one of the glass atmosphere scenes. The sound set was made by Mr. Carrol Shepphird, who is now making a miniature of the first Edison studio. The RKO studio has made available a collection of devices used for creating sounds artificially. The preservation and display of these devices is a debatable question; but as the improvements in recording apparatus will shortly eliminate them, it should be a good policy to preserve a record of them even though many in the industry may feel that the picture-going public should not be acquainted with this phase of picture making. A further record of the present has been made available by each of the studios in the form of a collection of still photographs showing their players in studio atmosphere. Many other items of the present are being preserved, so that an accurate record may be available of the trend of motion picture history. Any one having documents or literature showing new developments should send them to the Motion Picture Department of the Los Angeles Museum so that these records may be made complete for future reference.

The bringing together of the relics of the past has not been over-

* Presented at the Spring, 1933, Meeting at New York, N. Y.

looked. Mr. George E. Van Guysling, who was manager of the Biograph Co. from 1904 to 1907, and an exhibitor prior to that, added to the collection many historical relics. Included among these is a set of catalogues of the first 3000 pictures made by Biograph, a copy of the first *Film Index*, which was the first trade journal of the motion picture industry, and catalogues of companies that manufactured apparatus about 1900. Mr. Van Guysling brought to light the date of the first company to begin making pictures on the West Coast, the Biograph Co., which organized a studio in Los Angeles at 2623 West Pico St., on March 6, 1906. This date has been authenticated by various documents. The collaboration of Mr. Van Guysling with the Committee is greatly appreciated, and his display of many relics of the past is an interesting and valuable addition to the collection.

Another collection is the group of memoirs of the Vitagraph Co., made available by Mr. J. Stuart Blackton. In this accession is a large painting of the first Vitagraph open-air studio on top of the Morse Building on Nassau Street, in New York. This painting shows the set, as well as the furniture, which was painted on the wall of the adjoining building. Other items are a copy of the first magic lantern made by Athanasius Kircher, in 1640, early Zoötropes, a copy of the first fan magazine, autographed by Edison and all the members of the "Patents Company." Mr. Blackton also gave the museum a Biograph Mutoscope with a complete motion picture of 1908, showing pictures of the members of the Patents Company. This picture is in the form of a series of cards mounted on a hub. The cards are arranged to be flipped in order to show motion.

Mr. H. Lyman Broening presented an Edison projector and a complete set of bulletins of all Biograph pictures of 1908–09. It is interesting to note that this company made over 200 pictures during those two years, which varied from 500 to 900 feet in length. On the bulletins are pictures of motion picture players, many of whom are still famous, such as Mary Pickford, Mack Sennett, Florence Lawrence, Marion Leonard, Henry B. Walthall, and others.

Mr. Walt Disney made a display illustrating the making of a cartoon of Mickey Mouse. He also gave a set of drawings from his first three-color pictures as used in making animated cartoons.

Mr. Walt Lantz, who had the distinction of making the first cartoon in color, made available a copy of this cartoon, as well as examples of his work in cartoon processes in 1917. Mr. Ted Eshbaugh, another pioneer in color cartoons, is making a display.

Others assisting in the formation of this exhibit are Mr. Mack Sennett, who lent a representative group of early cameras, as well as memoirs of the early "Keystone Cop." Mr. Paul Panzer, who was known as the Pathé villain in the early days, has made available some posters of the nickelodeon theater of the time when the names of players were not publicized. Mr. Otto K. Olesen has presented a group of various arc lights that were used universally in making pictures prior to the advent of sound. The Bausch & Lomb Optical Co. has assured the Committee that it will make a display of lenses showing all types used from the earliest days of photography to the present. The RCA Victor Co. and the Western Electric Co. have promised displays illustrating their sound equipment. Mr. Leo G. Young in his searches through early periodicals has uncovered many interesting illustrations of early movie devices which he has copied for the exhibit.

One of the highlights of the exhibit is the display of original specimens of motion picture film. This collection includes samples of film dating back to the beginning of motion pictures, when both Friese-Greene and Edison were struggling with the idea of motion in pictures. There are also samples of the first raw stock made by George Eastman in 1889. In this collection, the majority of pioneers who made pictures before 1900 are represented by specimens of film from their work. A graphic history of color and motion pictures, as well as cartooning and other processes of the industry is afforded by this collection. There are examples of pictures made on paper, collodion, and metal. The film specimens are bound between glass plates, and are mounted in special cases having back-lighting facilities. Accompanying each specimen is a historical notation. All inventors who have perfected processes are requested to send samples of their work on film, so that a complete record of the ramifications of the motion picture may be preserved in this manner, to the chairman of this Committee, care of the New York office of the Society. Credit is given the donor on the museum label.

It would be impossible to list all the contributors who have assisted in the work of this committee; Wallace Clendenin, Ransom Mathews, Leo G. Young, Jackson J. Rose, Louis B. Mayer, Lee de Forest, Douglas Fairbanks, Bill Cotterell, Lee Shippey, Jack Lewis, Mario Larrinaga, Byron Crabbe, Silas Snyder, George Blaisdell, and Una Theisen are only a few of those whose assistance has been gladly rendered and greatly appreciated.

E. THEISEN, *Chairman*

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|---|---|
| G. A. CHAMBERS | W. V. D. KELLEY |
| B. W. DEPUE | G. E. MATTHEWS |
| O. B. DEPUE | T. RAMSAYE |
| C. L. GREGORY | A. REEVES |
| C. F. JENKINS | F. H. RICHARDSON |

A. F. VICTOR

## DISCUSSION

MR. K. KALLMAN: As the Society is endeavoring to establish an exhibit also at the New York Museum of Science and Industry, it might be appropriate to say a few brief words about the Museum and what it is doing.

The Museum is situated at 220 East 42nd Street, New York, N. Y. The exhibits, which are strictly educational, are devoted to the major divisions of what might be called the essentials of civilization: food, industries, shelter, transportation, textiles, and the like. Visitors are encouraged to handle the exhibits, and to push controlling buttons and to turn cranks. Most of the exhibits can be operated; in the communications section, for instance, is a model of a dial telephone arranged to show how it operates. There is an oscillograph arranged so that the visitor can see his voice vibrations. In transportation, there are wind tunnels, locomotive models, *etc.* A large section is devoted to electrical science, where are shown the complete development and theory of magnetism and electricity by means of models that are for the most part operative. The average attendance at the Museum is 800 per day.

The motion picture exhibit that we are trying to develop will be housed, we hope, in a room approximately 750 square feet in area. We should like to assemble an exhibit in New York primarily for two reasons. First, the motion picture industry actually began in New York. The old Biograph Company and some of the older companies started here. Second, we have the largest population, and a greater proportion of the population goes to see motion pictures in New York than any other place in the world. We feel that we want to build up this exhibit and try to rival Mr. Theisen's exhibit out in Los Angeles.

MR. J. I. CRABTREE: The question is, how are we going to do it? It will require a lot of money, even after we have contributed the apparatus. I do not know whether you have seen the Will Day exhibits in the South Kensington Museum in England. They are housed in mahogany and glass cases, and by turning a handle on the outside of the case, the exhibits can be made to work.

MR. KALLMAN: It is quite a problem to demonstrate the exhibits and to make them fool-proof so that they can not be broken or stolen; but that, I believe, is the problem of the Museum staff and I think we are able to cope with the situation. A purely historical exhibit would be interesting, but it is just as important to explain modern equipment—the theory of sound motion pictures, for example. We have already planned to have a demonstrating model of photoelectric cells and amplifier tubes and things of that sort. It is really our purpose to explain the newer things, and how they are being done, to the public of New York City.

MR. CRABTREE: Is the Museum interested purely in these working models, or in historical pieces of equipment—or both? If it is interested only in working

models, then it seems to me that this Museum is not the place for our equipment.

MR. KALLMAN: One of our typical exhibits is in the food section, where we have a series of models built to scale showing the development of plows. They are static exhibits, the first section showing a primitive man pulling a forked stick through the ground—the early method of plowing. The next section shows a later development, the application of the wheel; and finally, the seventh or eighth section shows the modern steel plow drawn by horses. It would have been too complicated to build a combined harvesting machine to scale, so at that point of the story we insert a motion picture—16 mm.— to complete the story of the development of plows.

So it is our problem not only to make the exhibits operate wherever possible, but also to present the historical background of the particular development as well.

# SOCIETY OF MOTION PICTURE ENGINEERS

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### 1933

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# SOCIETY ANNOUNCEMENTS

## JOINT MEETING OF BOARD OF GOVERNORS AND CHAIRMEN OF COMMITTEES

On the morning of April 24, at the Hotel Pennsylvania, New York, N. Y., was held a joint meeting of members of the Board of Governors and chairmen of committees of the Society. The purpose of the meeting was to discuss the relations between the various committees and their relation to the Society as a whole; to determine ways and means of assuring the greatest degree of collaboration between the committees; to define more carefully the scope of the work of each committee so that there may be no duplication of effort; and to provide an opportunity for each committee to learn of the methods followed by each other committee that have proved advantageous.

Eleven committees were represented at this meeting, which proved to be very fruitful in respect to arousing a clear understanding of the functions and relations of the committees, and of the ways in which they might be of greatest service to each other and to the Society. The general attitude of the industry toward supplying technical information and data to the committees received special consideration, particularly with reference to the curtailing of technical activities under economic duress.

The value of this first joint meeting was so evident that it is planned to hold a similar meeting in the future at each convention.

## NEW YORK SECTION

The regular monthly meeting of the New York Section was held on May 17, at the Electrical Institute, in the Grand Central Palace, New York, N. Y. Under the supervision of the Projection Practice Committee, Mr. H. Rubin, *Chairman*, the following papers were presented:

"The Professional Projectionist," by Dr. A. N. Goldsmith.
"Operating Disadvantages of Sound Screens," by Mr. F. H. Richardson.
"Effect of Oil on Film on the Screen Image," by Mr. G. C. Edwards.
"Factors Affecting Sound Reproduction in Theaters," by Mr. J. O. Baker.

The meeting was well attended, and considerable discussion followed the presentation of the papers. Some discussion occurred also concerning a proposed change of the form of the travel-ghost target included in the test reel presented to the Society with the report of the Projection Practice Committee at the New York Convention, on April 26. The new form of the target, as presented by Chairman Rubin, was approved by the meeting, and will be described in the report of the Committee when published in the JOURNAL.

## CHICAGO SECTION

The monthly meeting of the Chicago Section was held on May 11, at the Electric Association, in the Civic Opera Building, Chicago, Ill., preceded by an informal dinner. A report on the various features of the New York Convention was presented to the Section by Mr. R. F. Mitchell, *Chairman*, for the benefit of those who could not attend the Convention. Mr. Mitchell presented also summaries of the various technical papers, and described the general condition of the motion picture industry as reflected by the activities of the New York Convention.

The meeting was well attended; and, as it was the last meeting of the current season, plans were laid for the Fall activities of the Section, with the view of making that season even more successful than the past one.

## SUSTAINING MEMBERS

Bausch & Lomb Optical Co.
Bell Telephone Laboratories
Burnett-Timken Laboratories
Eastman Kodak Co.
Electrical Research Products, Inc.
National Carbon Co.
RCA Victor Co., Inc.

## HONOR ROLL

OF THE

## SOCIETY OF MOTION PICTURE ENGINEERS

*By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:*

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

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